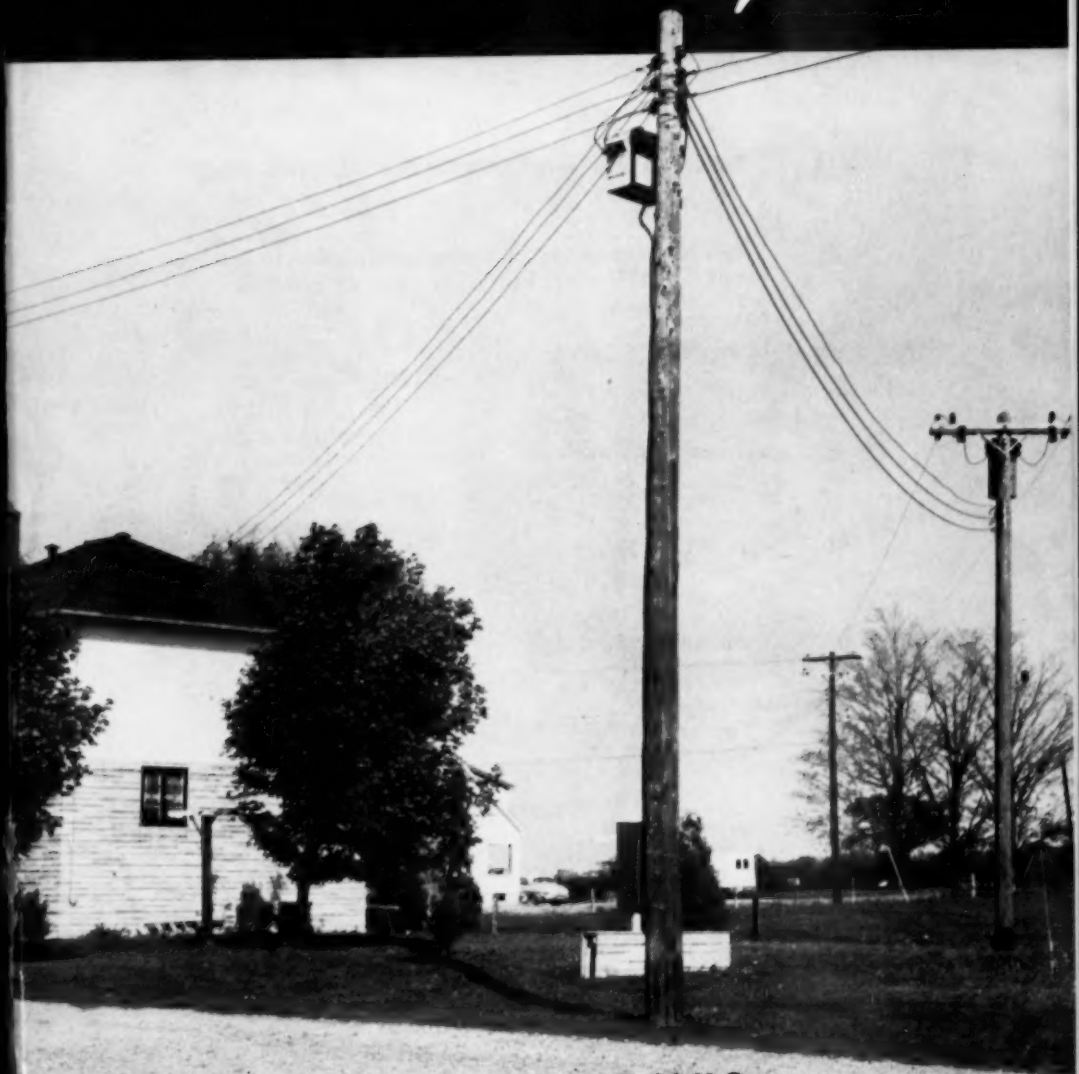
Cornell Extension Bulletin 849

Adequate FARM WIRING *Systems*



HOLLIS R. DAVIS

SYMBOLS

Lighting Outlet

Lighting Outlet and Pull Switch

Fan Outlet

Duplex Convenience Outlet

Duplex Convenience Outlet for Grounding-type Plugs

Special-purpose Outlet. Use subscript letters to indicate function. WH water heater, M motor, RH room heater

S Single-pole Switch

S_3 Three-way Switch

S_4 Four-way Switch

S_P Switch and Pilot Light

 Feeder

 Branch Circuit

Service Entrance Equipment

Distribution Panel for Feeders and/or Branch Circuits

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DEFINITION OF TERMS

General terms

Ampere is a unit of measure of the rate of flow of electricity through a wire, and may be compared with the rate of flow of water through a pipe. If a 60-watt lamp is used on a 120-volt circuit, ½ ampere of current will flow through the circuit.

Volt is a unit of measure of electrical pressure. A given number of volts pressure causes a certain number of amperes of electricity to flow through a wire. The usual pressure or voltage for farm services is 115 volts for small appliances and for light, and 230 volts for heating and for larger motors.

Watt is a unit of electrical power. It is a measure of the rate of electrical work and is the product of the volts times the amperes. One ampere of electricity flowing through a wire under 1 volt of pressure represents 1 watt of power. If 5 amperes flow in a circuit under a pressure of 115 volts, 575 watts of work are being done.

Kilowatt is 1000 watts. This is used because a watt is a very small unit of power.

Kilowatt hour is the unit that measures the work done. It is 1 kilowatt working for 1 hour or the product of power in kilowatts and time in hours. For example, if 2 kilowatts are used for 4 hours, 8 kilowatt hours of energy will be used, or if 800 watts (0.8 kilowatt) are used for 3 hours, 2.4 kilowatt hours are used. Electrical energy is metered and sold by the kilowatt hour.

Horsepower is a unit of power which is theoretically equal to 746 watts. One kilowatt equals about 1⅓ horsepower. No motor is 100 per cent efficient; therefore, when one estimates the operating cost of a motor of 1 horsepower or larger, it is better to estimate on the basis of 1 horsepower equals 1000 watts. For fractional horsepower motors, it is better to estimate on the basis of 1 horsepower equals 1200 watts. For example, a ¼-horsepower motor operating for 2 hours at 300 watts per hour would use about 600 watt hours, or about ⅔ kilowatt hour, and a 2-horsepower motor operating for 2 hours at 2000 watts per hour would use about 4000 watt hours, or 4 kilowatt hours.

A name plate on each motor gives the approximate amperage the individual motor will use when delivering its rated horsepower.

Ohm is a unit of measure of the resistance to the flow of electricity through any material.

Voltage drop is a term given to the loss in pressure when electricity flows through a wire. Voltage drop results in a loss of light, power, and heat when electrical equipment is operated.

Lighting outlet is the wired box to which various types of lighting fixtures may be fastened.

Convenience outlet is the plug-in receptacle, as well as the box in which it is housed.

Special-purpose outlet is a point of connection to the wiring system which, because of its location or type, is usually limited to the particular equipment it is intended to serve.

Voltages when mentioned as 115 or 230 volts are understood to be nominal and to include, respectively, voltages of 110 to 120 and 220 to 240. This bulletin uses 115 and 230 volts in computations and examples.

Overcurrent protective devices

Fuse is a short ribbon or wire of a low-melting point alloy inserted in the wiring circuit as protection against overloading or short circuiting the wires. A fuse is of a certain size to carry a given amperage indefinitely, but will melt and break the circuit when there is a flow of amperes larger than the given rating.

Time-delay fuse is a fuse that has the ability to carry overload currents of short duration without melting. The heavier the overload, the less is the time required for the fuse to "blow." In motor circuits, where the starting currents are high but of short duration, this type of fuse need not have so high a rating as an ordinary fuse to permit the motor to be started. When properly selected and installed to carry only the current of a single motor, such fuses can be used also to provide motor-running (overload) protection. Like the common fuse, the time-delay fuse is also made in plug and cartridge types.

Circuit breaker, a device used instead of a fuse, is inserted in a wiring circuit as protection against overloading or short circuiting the wires. Circuit breakers are made in various sizes corresponding to current-carrying capacities of different sizes of wires. The circuit breaker resembles a toggle switch in outward appearance. When overloaded, it automatically trips and shuts off the flow of current. A circuit breaker must be reset to the "on" position by hand. The circuit breaker may be used as a toggle switch to disconnect a branch circuit.

Motor-protective devices

The purpose of motor-protective devices is to protect the motor against overcurrent caused by overload on the motor or by low voltage. They must be designed and selected to trip when the motor current exceeds a safe limit for too long a period of time, but should have enough time element to keep them from tripping during the starting period which lasts only for a short time. Motors should be protected also against high temperature. Several standard devices may be used for this purpose.

Thermal relay, a device usually incorporated in the motor starting switch, causes the switch to open on moderate long-time overloaded current. It has the necessary time-element feature to allow the motor to start.

Thermal cut-out, a device that has a time-element feature, requires replacement of a solder link after it has opened the circuit because of excessive overload current.

Inherent protective device is built into the motor and is designed to open the motor circuit on excessive overload current or on temperature rise due to poor ventilation or lubrication.

Circuit breaker with a time-element trip may be used provided the rating or setting of the breaker is selected low enough to properly protect the motor.

Time-delay fuse may be used if it is selected to have a current rating not appreciably higher than the full-load rating of the motor so that it will "blow" on moderate long-time overload currents.

Adequate Farm Wiring Systems

Hollis R. Davis

THE farmer uses electricity for light, power, and heat, to save labor, to reduce the cost of production, and for convenience. The efficient use of electrical equipment depends on a well-planned and well-installed wiring system. The basic requirements of such a system are that it is large enough to supply the present needs and to allow for future expansion and for additional equipment; it should be economical to operate, convenient, and safe.

To plan a system that will safely and effectively care for all the equipment and services, it is necessary to know the meaning of the terms used in electrical wiring (page 5), how these terms are applied, and the materials used. This bulletin tells how to determine the wiring needed, and gives some examples for specific buildings.

Resistance

RESISTANCE to the flow of electricity in a wire causes a loss in voltage. Small wires have a greater resistance than large wires, and longer wires have a greater total resistance than do short wires. Therefore, to allow electricity to flow freely through a wire without serious loss of voltage, it is necessary to use the correct size of wire. For example, a load of 10 amperes at 230 volts, or 2300 watts, for a distance of 40 feet requires No. 14 wire but at 80 feet requires No. 10 wire to allow for the greater resistance over the longer distance (table 7, page 66).

The effect of resistance as it affects heat, light, and motors may be shown by the following illustrations.

Heat

The decrease in heat produced by an electrical device is about *twice* the percentage decrease in the voltage applied to the device. If the voltage applied to a heating element is 100 per cent of rated voltage, the correct heat results. With 5 per cent less voltage (95 per cent rated voltage) applied to the element, the heat produced in the element is reduced 10 per cent (twice the decrease in voltage). The loss is due to the resistance caused by too small or too long a wire. This means longer heating time at higher cost and inconvenience. For example, a loss in voltage affects the heating time of a water heater. One kilowatt will raise 4 gal-

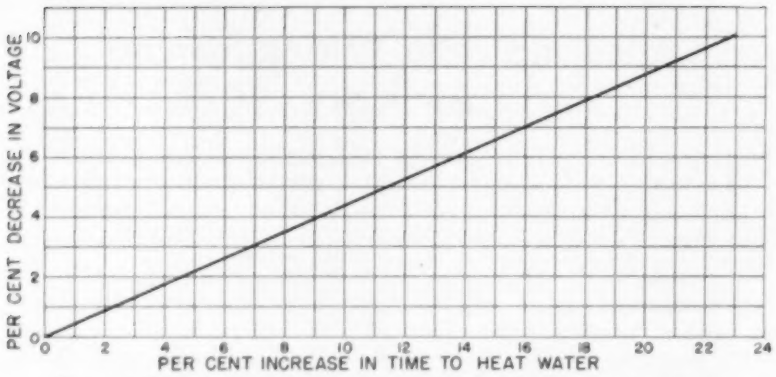


Figure 1. Increase in time required to heat water due to losses in voltage

lons of water 100°F. in one hour. If the voltage is reduced 10 per cent, then 90 per cent voltage × 90 per cent amperes = 81 per cent watts. Eighty-one hundredths of a kilowatt hour will raise 4 gallons of water 100°F. in 1.234 hours. Similarly, 1 kilowatt hour will raise 22 gallons of water 100°F. in 5½ hours, and 0.81 of a kilowatt hour will raise 22 gallons 100°F. in 6¼ hours. In general, a 10 per cent decrease in voltage will increase the time to heat water at least 23 per cent.

Light

A small voltage drop results in a much lower light output, or a dimming of the lights. A 1 per cent drop in voltage causes a 3 per cent loss in light. The light then will be 97 per cent of rated output. A lamp rated at 115 volts when operated on a circuit with a 10 per cent voltage loss (103.5 volts) gives only 70 per cent of its normal light.

If one installs larger lamps to overcome the loss of light due to low voltage, then the voltage loss may be greater and operating costs will be needlessly increased.

Motors

Low voltage throttles the power of a motor. When starting a 115-volt motor, it develops only 64 per cent of its power if the voltage drops to 92 volts. Therefore, it may not start its load but will draw a higher current and is likely to burn out. If the operating voltage is 90 per cent of rated voltage, the power output of the motor under load is only 81 per cent. For example, a 5-horsepower motor would develop about 4 horsepower. If the applied voltage is too low, the motor may overheat and damage the motor coils unless the motor is protected by a suitable overload switch.

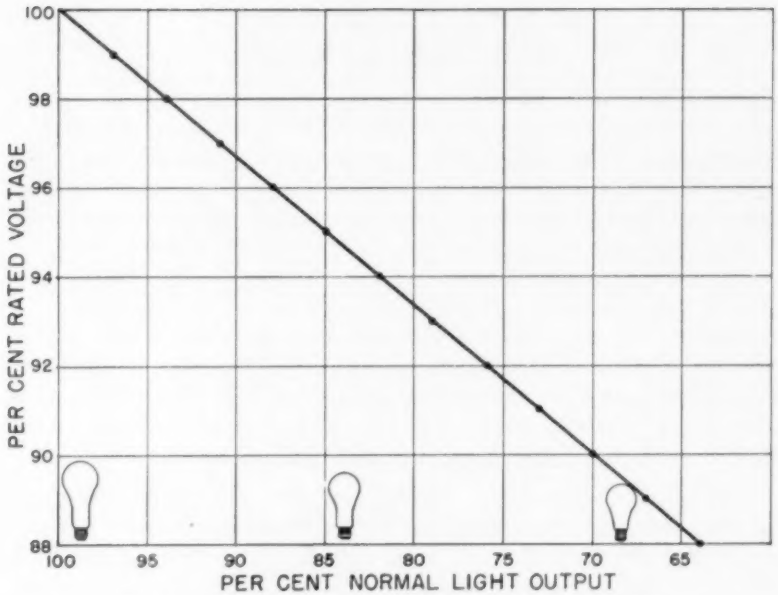


Figure 2. Effect on light output due to losses in the voltage

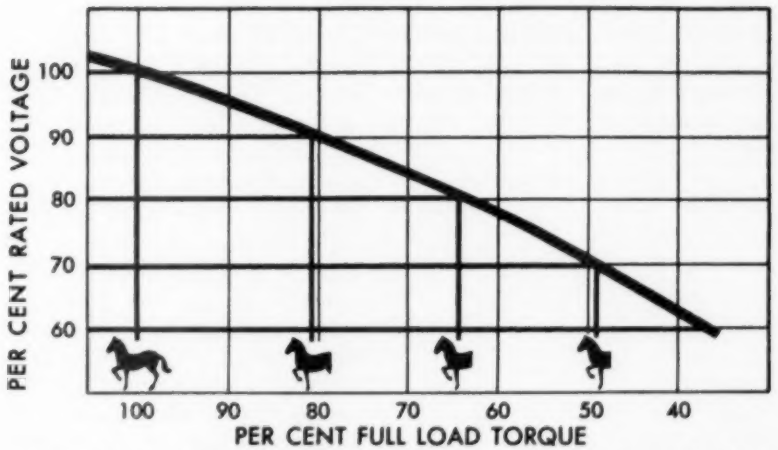


Figure 3. Effect of reduced voltage on the power of a motor. Lowered voltage reduces the turning effort (or torque) of a motor. Fractional horses represent reduced horsepower.

Some Relationships

Watts, Volts, and Amperes

THE fundamental relationship of watts (W), volts (E), and amperes (I) can be expressed by the formula $W = EI$. If the voltage and the amperage of an appliance are known, the watts are found by multiplying E by I. For example, an appliance that uses 5 amperes (I) and has a voltage of 115 volts (E) uses 575 watts (W). If wattage and voltage are known, amperage may be found as $I = \frac{W}{E}$. For example, the wattage is 920, the voltage is 115, and the amperage unknown. If the wattage of 920 is divided by the voltage of 115, the result is 8 amperes. *This formula applies for heating and lighting equipment only,* not for motors.

Volts, Amperes, and Resistance

The relationship between volts (E), amperes (I), and resistance (R) in ohms is expressed by Ohm's Law: Volts (E) = amperes (I) × resistance (R). Therefore, $E = IR$ shows that the voltage lost in a circuit of any given size of wire is a product of the resistance of the wire and the amperage. The watts lost in a circuit for any given wire depends on the voltage drop (E) and on the amperage (I).

The resistance of copper wires of various sizes are given in table 1.

It has been stated that $W = EI$ and also Ohm's Law that $E = IR$. If IR is substituted for E in the first formula, the result is $W = IR \times I$ or $W = I^2R$. Thus power lost in a circuit is proportional to the square of the amperage. No. 14 wire has a resistance of 0.26 ohm per hundred feet (table 1). Thus a circuit of two No. 14 wires 100 feet long has a resistance of 2×0.26, or 0.52 ohm. If a ½-horsepower motor is operated on this circuit on 115 volts, the voltage drop is 7 amperes $\times 0.52$ ohm, or 3.64 volts and at starting, approximately 21×0.52 ohm, or 10.92 volts. Similarly, the power lost is $7 \times 7 \times 0.52$, or 25.48 watts running and 229.32 watts starting.

Table 1. Resistance of Copper Wire
(Maximum resistance in ohms per 1000 feet)

Size (American Wire Gage)	Resistance
Number	*Ohms*
14	2.57
12	1.62
10	1.02
8	0.64
6	0.40
4	0.25
2	0.16
1	0.13
0	0.10
00	0.08
000	0.06
0000	0.05

If the circuit is changed to 230 volts, the current is cut in half while the resistance is unchanged. The voltage drop under running conditions then becomes 3.5 amperes × 0.52 ohm, or 1.82 volts, and at starting 10.5 amperes × 0.52 ohm, or 5.46 volts. The power lost now becomes 3.5 × 3.5 × 0.52, or 6.37 watts under running conditions and 10.5 × 10.5 × 0.52, or 57.33 watts starting. In short, doubling the voltage for a given load reduces the voltage drop one-half, but cuts power loss to one fourth.

Another example to illustrate this problem is two brooders of 720 watts each, 120-volts pressure, and located 100 feet from the distributing panel. Each brooder uses 720 watts divided by 120 volts, or 6 amperes, or a total of 12 amperes for the two brooders. If these brooders are used on one circuit, each of the two wires will carry 12 amperes. To carry this load with a maximum of 1 per cent voltage drop for this distance, No. 6 wire is needed (table 8). A loss of 1 per cent in voltage on a straight resistance load causes a 1 per cent reduction in the current. This reduction in current is not enough to change the figures, therefore the current of 12 amperes will be used.

The power lost is 1.2 volts × 12 amperes = 14.4 watts. The power delivered to the brooders is 1426 watts, or 713 watts each or a loss of 1 per cent. If the brooders are on half of the time, then the energy used is 1440 watts × 12 hours × 30 days = 604,800 watt hours, or 604.8 kilowatt hours. The loss in the circuit is equal to 14 watts × 12 hours × 30 days = 5040 watt hours, or 5.04 kilowatt hours. At 2 cents per kilowatt hour this would result in a loss of 10 cents a month.

No. 10 wire would normally be used on an appliance circuit and with it the voltage drop would be approximately 5 volts, or 4.1 per cent. A drop of 5 volts will not permit the brooders to draw their full 6 amperes each but will reduce the current by a like percentage of 4.1 per cent to about 5.75 amperes per brooder or 11.5 amperes total. The watts delivered by each brooder will be 115 × 5.75, or 661 watts, or an 8.2 per cent loss in heat. The watts lost in the circuit will be 5 volts × 11.5 amperes = 57.5 watts, or 4 times as much as in the previous example. An 8 per cent loss in heat output would cause the brooders to operate at least 8 per cent longer, or 12.96 hours per day. The electricity used in a month measured at the distributing panel will be 120 volts × 11.5 × 12.96 hours × 30 days, or 536,520 watt hours or 536.52 kilowatt hours. The loss in the circuit is 59 watts × 12.96 hours × 30 days, or 22,939 watt hours, or 22.9 kilowatt hours per month. This loss at 2 cents per kilowatt hour would amount to at least 45 cents a month for this one use of electric power. The operating cost of the brooder has therefore increased, the heat delivered to the brooder has decreased, and the additional cost of the current

has gone into heat losses in the circuit. If there is a greater voltage loss or drop, the brooders might be on all the time yet never reach operating temperature, resulting in increased mortality of the flock.

Cables, Wires, Non-Metallic Surface Wiring Devices, and Protective Devices

Cables

Non-metallic sheathed cable (figures 4, 5, 6, and 7) is recommended as the best all-around cable for farm buildings. It is inexpensive and safe.

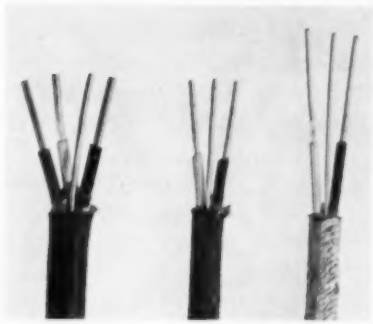


Figure 4. Non-metallic sheathed cables, Type NM for interior wiring in dry locations on farms. *Left to right:* 3-wire No. 10 with ground, 2-wire No. 12 with ground, and 2-wire No. 14 with ground

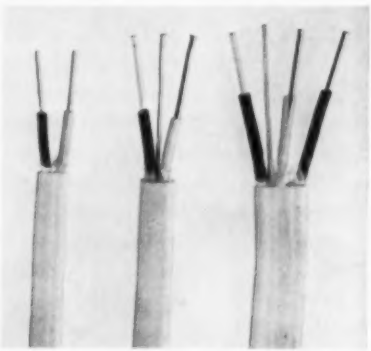


Figure 5. Non-metallic sheathed cables, Type NMC, for use in extremely moist conditions. When this cable is labeled *Type UF,* it can also be used for direct burial in earth.

Left to right: 2-wire No. 14, 2-wire No. 12 with ground, 3-wire No. 12 with ground

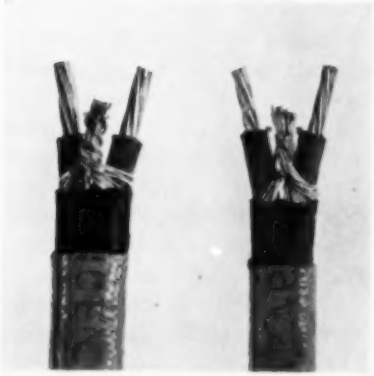


Figure 6. One type of service-entrance cables used to bring electricity from the service drop wires, or feeder wires, down the side of a building to the service switch.

Left to right: No. 4 three-wire service-entrance cable and No. 6 three-wire service-entrance cable

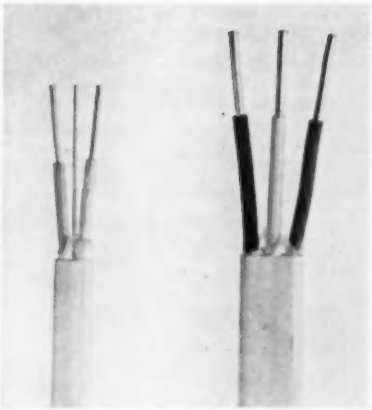


Figure 7. Non-metallic plastic covered cable type UF suitable for underground and general use.
Left to right: 2-wire UF No. 14 with ground and 3-wire UF No. 10

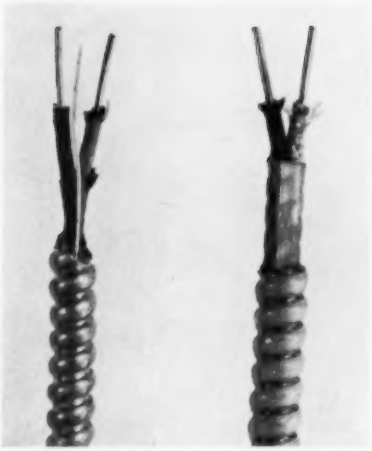


Figure 8. Metallic sheathed cable for use in dry locations and lead-covered metallic sheathed cable for use in moist locations. Generally used in locations subject to mechanical injury.
Left to right: 2-wire No. 14 with ground and 2-wire No. 12 lead sheath

Corrosion-resistant plastic or synthetic outer coverings are highly recommended for farm buildings, particularly in wet locations.

Metal-clad cables (figure 8) often rust and corrode in the presence of moisture and ammonia and are not well adapted to farm buildings that house livestock.

Carrying capacities of the common sizes of rubber-covered, thermoplastic, and weather-proof wires in cable are given in table 2 (page 14).

Wires

Ground wires (figure 9) provide a path to earth for stray electrical currents which might otherwise create a fire or shock hazard. The size

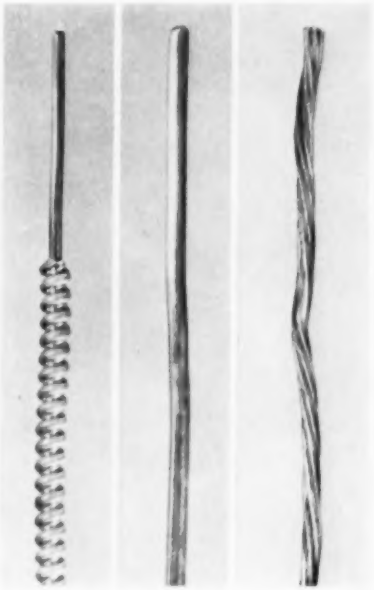


Figure 9. Three common types of ground wires
Left to right: No. 8 armored, No. 4 bare, and No. 4 stranded

Table 2. Carrying capacities of the more common sizes of rubber-covered, thermoplastic, and weather-proof wires*

Size A W G or M C M	Rubber-insulation type R, RW, RU; thermoplastic insulation type T, TW in cable	Rubber-insulation type RH in cable	Weather-proof insulation in air	
			Type WP	Type TW
Number	*Amperes*	*Amperes*	*Amperes*	*Amperes*
14	15	15	...	...
12	20	20	...	...
10	30	30	55	40
8	40	45	70	55
6	55	65	100	80
4	70	85	130	105
2	95	115	175	140
1	110	130	205	165
0	125	150	235	195
00	145	175	275	225
000	165	200	320	260
0000	195	230	370	300
250	215	255	410	340
300	240	285	460	375
350	260	310	510	420
400	280	335	555	455
500	320	380	630	515
600	355	420	710	575
700	385	460	780	630
800	410	490	845	680
900	435	520	905	730
1000	455	545	965	780

* These are the limiting capacities of copper wires beyond which excessive temperature may damage the insulation. National Electrical Code 1953. The allowable current carrying capacity of aluminum wire of the same size is 84 per cent of that shown in table 2.

Figure 10. Interior wires for inside wiring circuits, with conduit or knob and tube wiring

Three common types are R, RH, and T, known respectively as *code, heat resistant,* and *thermoplastic wires*

Left to right: No. 8 RH, No. 4 stranded R, No. 14 T, and No. 12 stranded T-copper conductors

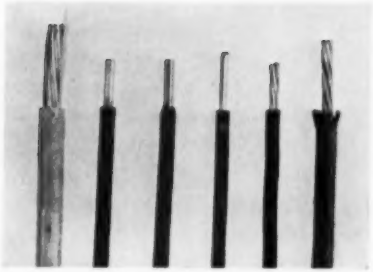


Figure 11. Outside or weatherproof wire for use between buildings
Left to right: No. 2 type T stranded copper conductor, No. 6 type WP aluminum conductor, No. 6 type WP copper conductor, No. 8 type TW copper conductor, No. 8 type TW stranded copper conductor and No. 4 type WP stranded copper conductor

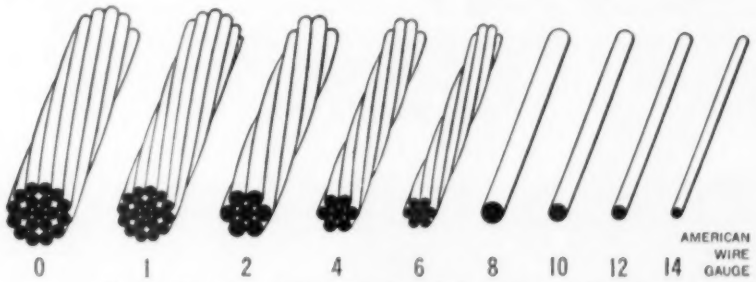


Figure 12. Approximate size of typical copper conductors

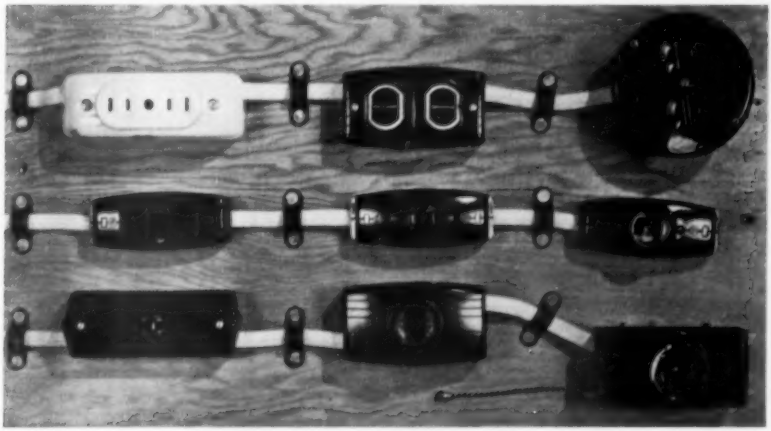


Figure 13. Non-metallic surface wiring devices used with plastic cable and straps
Top (left to right): Porcelain duplex receptacle, plastic duplex receptacle, and bakelite duplex receptacle
Middle (left to right): Duplex receptacle, single-pole switch, and lamp holder (all screwless pressure grip terminals)
Lower (left to right): Single-pole switch, lamp holder, and lampholder with pull chain (plastic)

of the ground wire is determined by the size of the service.

Wires (figures 10 and 11) are primarily used for distribution systems and feeders between buildings. The current carrying capacities of wire in air are greater than wire in cable (table 2, page 14).

Non-metallic Surface Wiring Devices (figure 13)

Non-metallic surface wiring devices are used in farm buildings because they are resistant to moisture and corrosive conditions. There is less hazard from electrical shock with these wiring materials. Grounding of these devices is not necessary. Special grounding type receptacles are available for appliances to be used in these circuits.

Protective Devices

Fuses

Plug. Common plug-type fuses (figure 14) are used for 115-volt or 230-volt circuits. These fuses are rated at 10, 15, 20, 25, and 30 amperes. Fuses with ratings below 10 amperes can be had for special purposes.

Cartridge. Cartridge fuses are the only type available to carry more than 30 amperes of current. The ferrule contact type (figure 15) may be used up to 60 amperes. The knife-blade type (figure 16) may be used up to 600 amperes. Cartridge fuses are available in a wide range of amperage and voltage ratings.

Figure 14. plug fuses
Clockwise from the top: 1-, 5-, 15-, 20-, 25-, and 30- ampere plug fuses

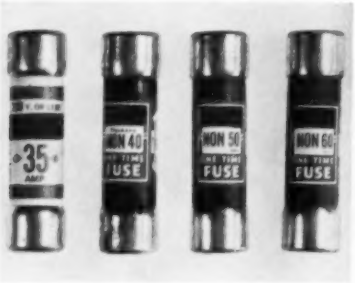


Figure 15. Ferrule contact cartridge-type fuse.
Left to right: 35-, 40-, 50-, and 60-ampere fuses. Ferrule contact cartridge-type fuse is available for a smaller fuse clip from 15 to 60 ampere

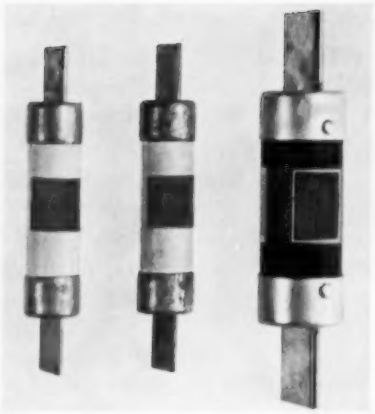


Figure 16. Knife-blade cartridge fuses
Left to right: 70, 100, and 200 amperes. These are available in amperage ratings of 65 to 600

Time-delay. Time delay fuses (figures 17 and 19) give the same short-circuit protection as an ordinary fuse but have the ability to carry overloads of short duration, such as the starting of an electric motor. These fuses are also made in the cartridge type (figure 18).

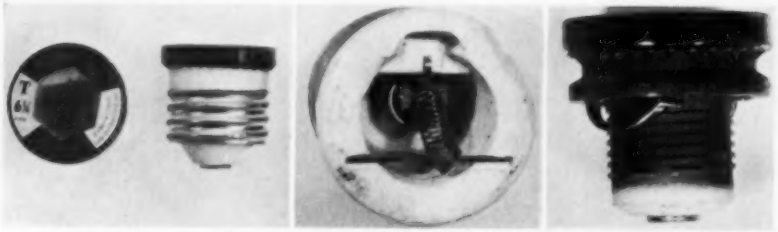


Figure 17. Close up of plug type time-delay fuses available in 1- to 30-ampere sizes
Left to right: 6¼-ampere time-delay fuse; fuse element; special fuse to be used with an adapter

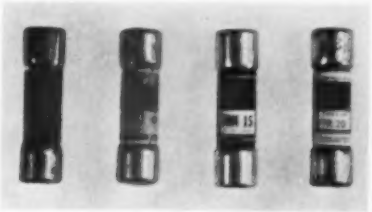


Figure 18. 6-, 10-, 15- and 20-ampere time-delay cartridge type fuses—available in two clip sizes from 5 ampere to 60 ampere

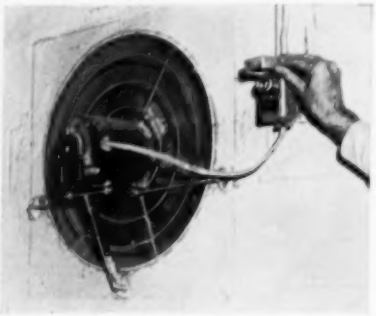


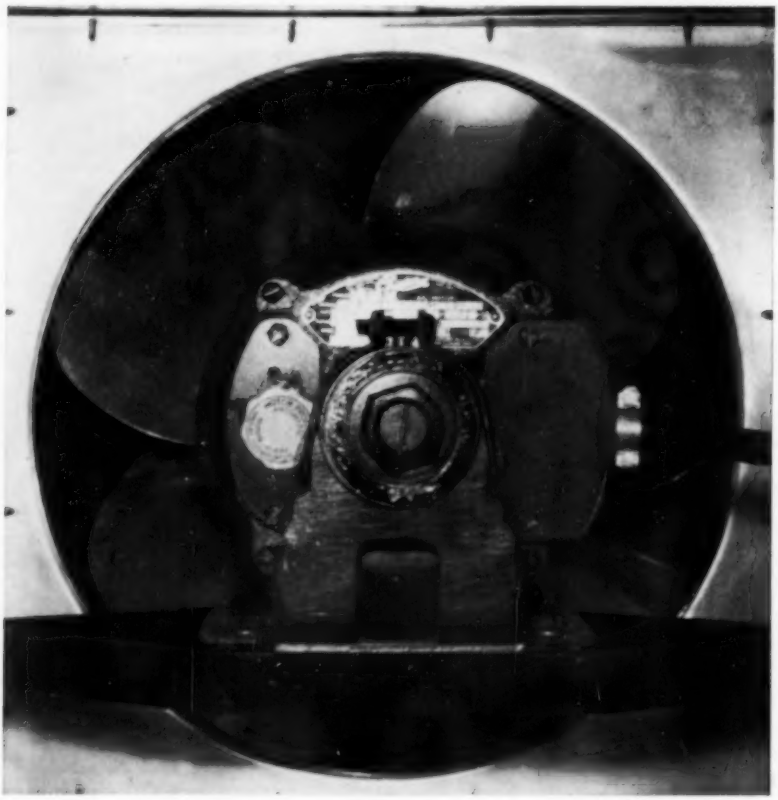
Figure 19. Manual starting switch with time-delay fuse used with a fan

Thermal Overload Element

"Built-in." This type (figure 20) of overload protective device is "built into" the frame of the motor. It protects the motor from excessive overload, low voltage, and high operating temperatures. This type may or may not reset itself automatically.

Thermal overload, used in a switch. This type (figures 21 and 22) of thermal overload protective device protects a motor against excessive overload and low voltage. The elements are rated in various amperages and should be sized to the motor they are to protect. Most of these switches that use a thermal must be reset to restart the motor.

Figure 20. A thermal overload protective device "built in" the motor. This type resets itself and the motor starts again automatically



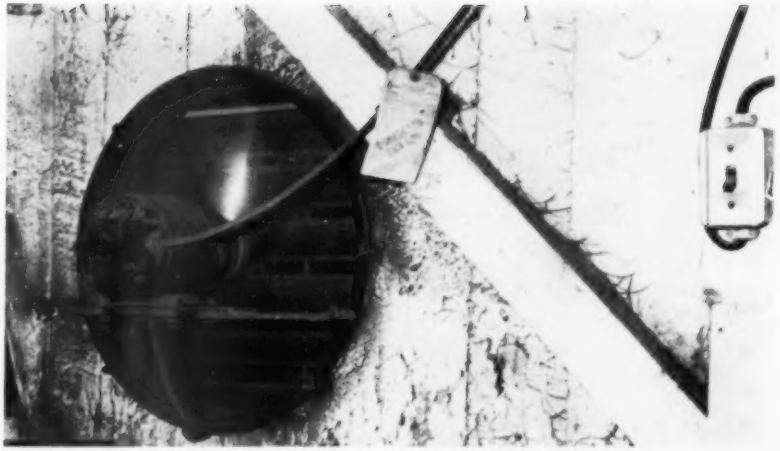


Figure 21. A thermal overload switch, upper right. This switch is designed especially to protect electric motors and to start and stop the motor. This type must be reset manually. Further information is given in Cornell Extension Bulletin 673, *Protection for Electric Motors,* by E. S. Shepardson

Figure 22. Magnetic starting switch with thermal overload used to protect a hay-drier motor

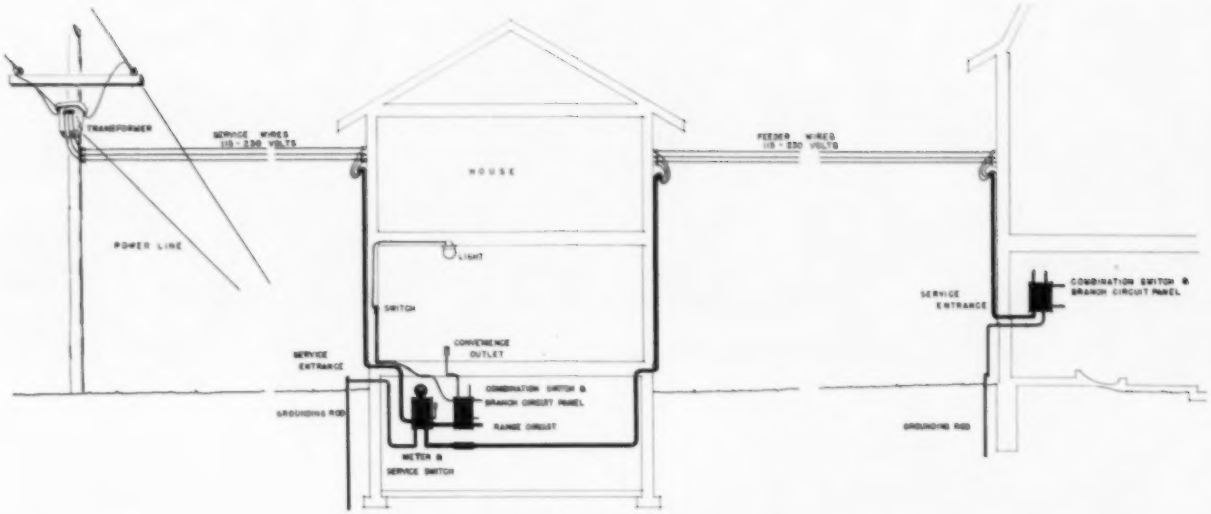


Figure 23. A 115/230-volt farm wiring system

Note the four main parts: (1) the main service, (2) the feeder wires from the house to the barn, (3) the barn service, and (4) the circuits in the house and the barn. Pole metering (figure 48) shows the electric company service, with separate services from the meter pole to each of the buildings

Four Parts of the Wiring System

A FARMER will be assured of good voltage if he has a well-planned and well-installed system. He should keep the basic requirements—**adequate capacity, economy, easily expanded, convenience,** and **safety**—in mind while considering the following four parts of the wiring system (figure 23).

Circuits and outlets
- Heat, light, and power circuits and outlets
- Carrying capacity of circuits

Building service
- Entrance conductors and fused switch

Feeder wires to buildings

Main service entrance
- Fused switch and distribution panel

Circuits and Outlets

Circuits

A circuit consists of two wires that provide a path for the flow of electricity from the source (distribution panel) to the point of use. There

Figure 24. Lamps taking current from a circuit and converting electricity into light

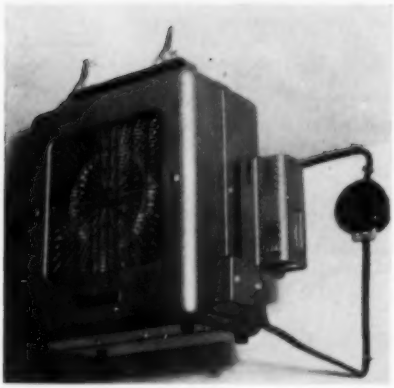
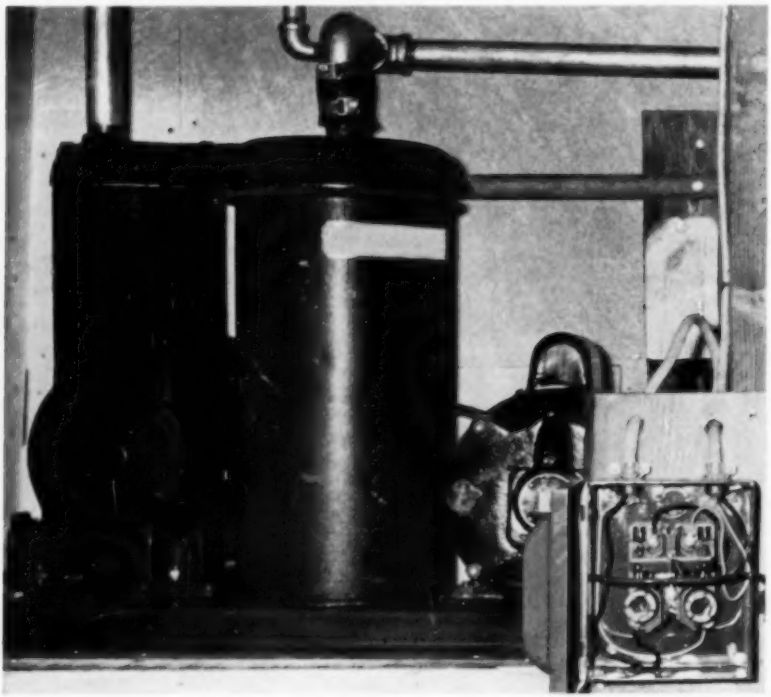


Figure 25. A heater taking current from a circuit and converting electricity into heat for the milkhouse

are in each building one or more circuits. An outlet provides a point to take electric current from the circuit and by the use of electrical equipment convert it into light, heat, and power (figures 24, 25, and 26).

Figure 26. An electric motor taking current from a circuit and converting electricity into power for the milking machine



Outlets

There are three types of outlets—lighting, convenience, and special purpose.

Lighting. A lighting outlet (figure 24) refers to an outlet to which various lighting fixtures may be attached to use and convert electricity from the circuit into light.

Convenience. A convenience outlet (figure 27) refers to an outlet box and cover for a plug-in receptacle for small electrical equipment, such as electric clippers, small motors, lamps, or heaters.

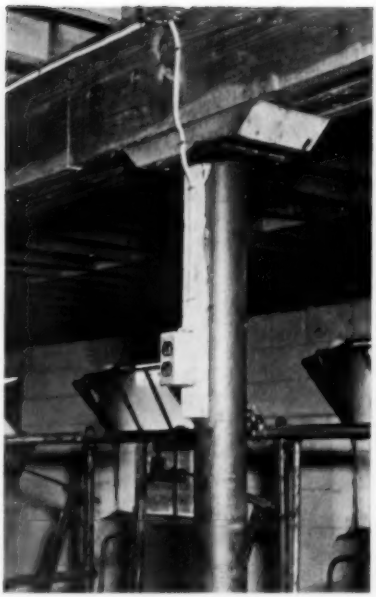


Figure 27. A circuit with convenience outlet

Special-purpose. A special-purpose outlet (figure 28) is an outlet that is limited because of location or type to the use of the particular equipment it is designed to serve. Examples of this type of outlet are for heaters, water heaters, motors to operate haydriers, fans, gutter cleaners, and bulk milk coolers.

Figure 28. Heavy-duty 3-pole outlet that may be used for large motors

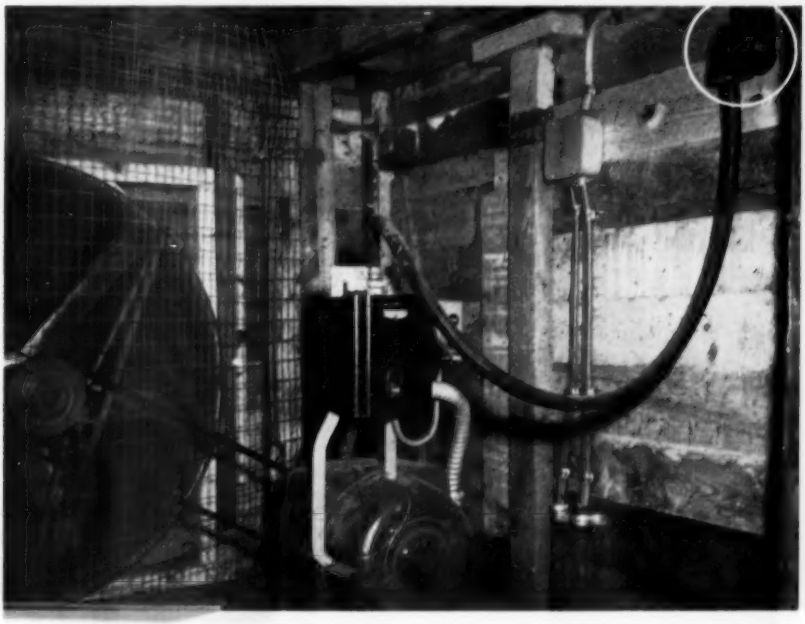


Figure 29. An electric drill connected to a 20-ampere branch circuit

Carrying Capacity of Circuits

Branch-circuit wires are usually rated to carry 15, 20, 30, or 50 amperes. The 15-ampere branch circuit is used for permanently connected lighting equipment and for convenience outlets (figure 27) for small appliances such as clippers, electric drills, and trouble lamps.

As a guide in designing these branch circuits, each outlet should be calculated as 1.5 amperes, or 175 watts (1.5 amperes $\times$ 115 volts) with a maximum of 10 outlets per circuit (10 $\times$ 1.5 amperes, or a 15-ampere circuit). If an outlet has an amperage larger than 1.5, the number of outlets should be reduced accordingly. Each circuit should be protected by a 15-ampere fuse. No. 14 wire safely carries this amount of current and is generally used, although larger wire should be used if the circuit is very long. No. 12 wire is now being used extensively on lighting, motor, and appliance circuits.

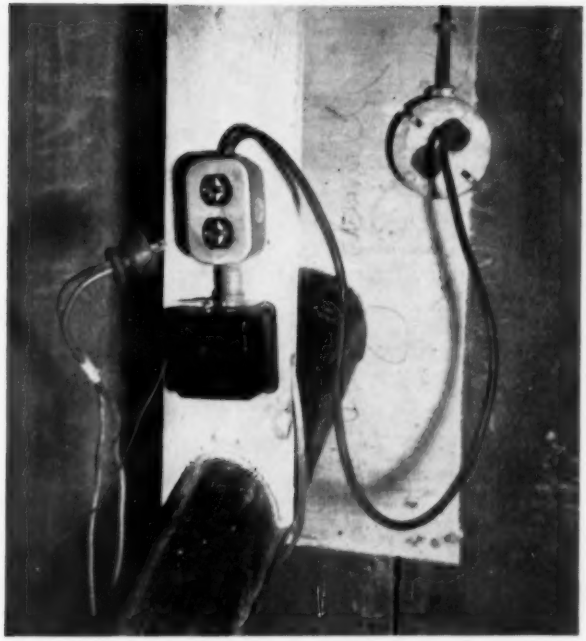


Figure 30. Electric heating cable connected to a 20-ampere branch circuit to protect a water pipe from freezing

The 20-ampere branch circuit (figures 29 and 30) is used for convenience outlets for such appliances as immersion heaters, water warmers, small motors, and lighting outlets[1]. A maximum of 10 outlets should be allowed for any one circuit, and each circuit should have 20-ampere fuse protection. No. 12 wire must be used for this amount of current. For longer runs, even larger wire may be necessary.

The individual equipment circuit should be used for all permanently connected or installed motors of ½ horsepower and larger, all permanently connected equipment more than 1000 watts, and equipment such as water systems, milking machine motors, milk coolers, water heaters, and hay-drier motors (figures 31 and 32). Heavy-duty heating units, water heaters, electric motors ½ horsepower or larger, and similar equipment, should be connected to 230-volt circuits.

Branch circuits serving chick brooders and other electrical equipment upon which life processes depend, should be designed for not more than

[1] 1953 Code permits 20 ampere circuits to be used as a general purpose circuit.

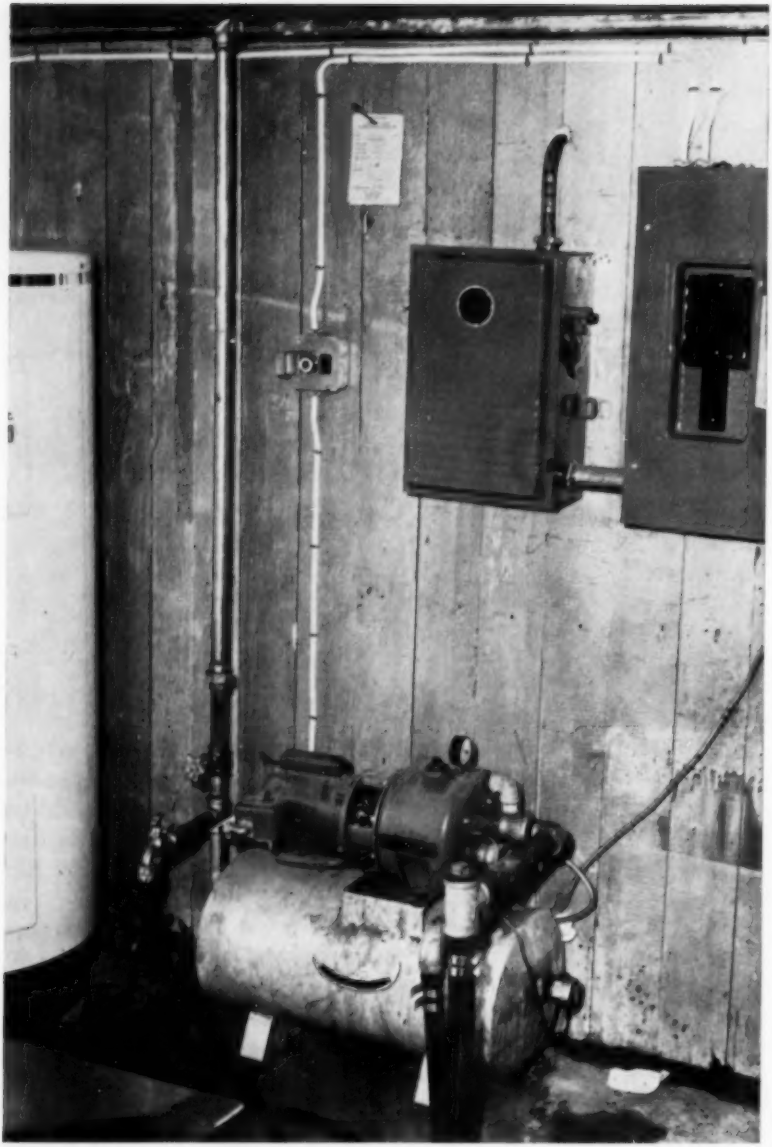


Figure 31. Individual-equipment circuit for a water pump. Note circuit breaker at upper right and manual-operated switch with time-delay fuse in center of picture

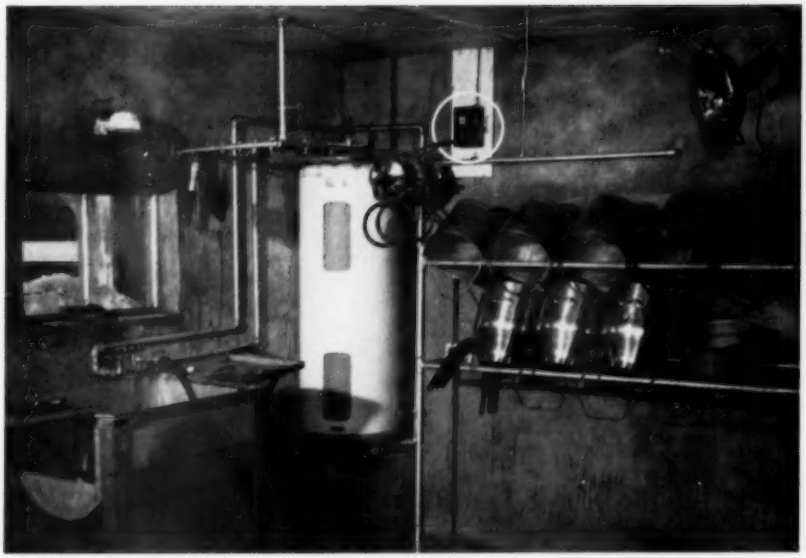


Figure 32. Individual-equipment circuit for an electric water heater

a 1 per cent voltage drop. Other individual circuits should be designed for not more than a 2 per cent voltage drop.

All equipment should be protected by the size of the fuse of thermal device determined from the amperage, type of equipment, and carrying capacity of the wire.

The total amperes of the lights and equipment on all the circuits in the building make up the total computed load that must be supplied through the service switch, which is one part of the service-entrance equipment.

Building Service

The service to individual buildings consists of the necessary wires and wiring devices that provide a path for electricity to enter each building (figure 23). The service consists of service drop or feeder wires, service-entrance cable, disconnecting means or service switch, over-current protection and a ground connection.

Service "drop" wires are defined by the Code as "that portion of overhead service conductors between the pole and the first point of attachment to the building." It may also mean the portion of the overhead wires between the transformer pole and the metering "pole," if a pole meter is used.

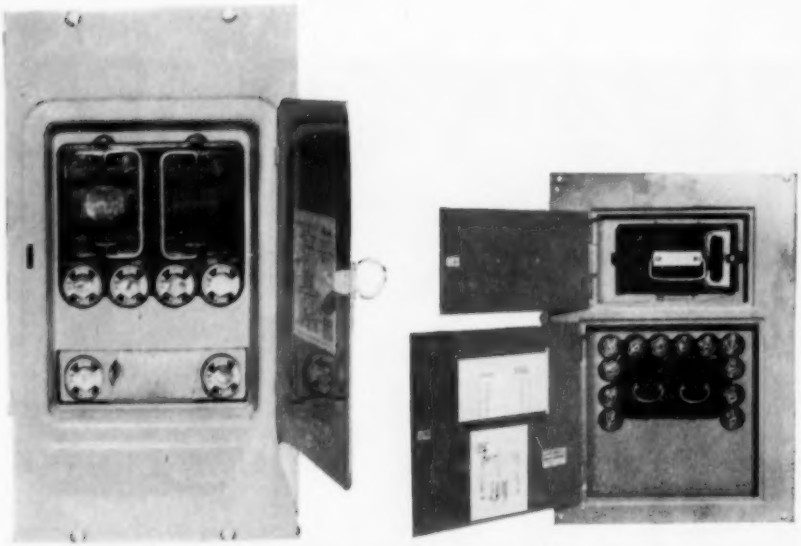


Figure 33. "Combination" type service-entrance switch and fuse panels
Left: 60-ampere 3-wire, 115/230-volt service entrance switch and fuse panel
Right: 100-ampere 3-wire, 115/230-volt service entrance switch and fuse panel

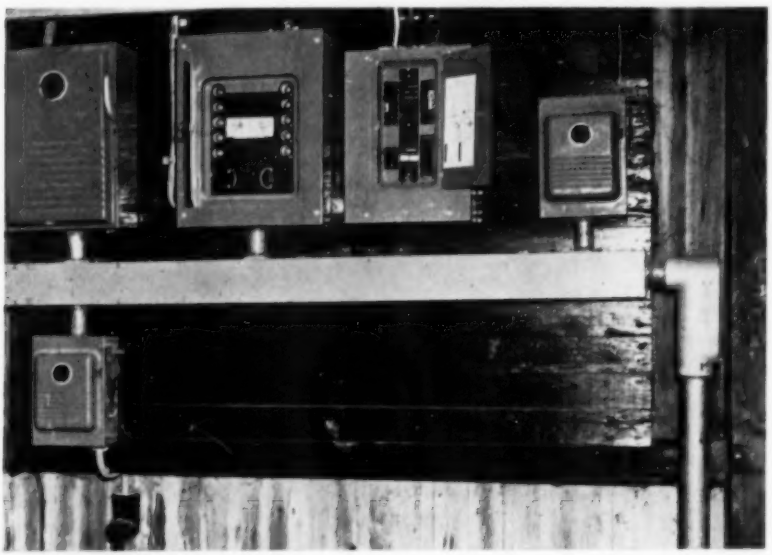


Figure 34. 200-ampere service in barn, served by meter on the outside of the barn. Requires less than 6 operations to "cut off" all service. *Note* fuse panels and circuit breaker panels in center of picture

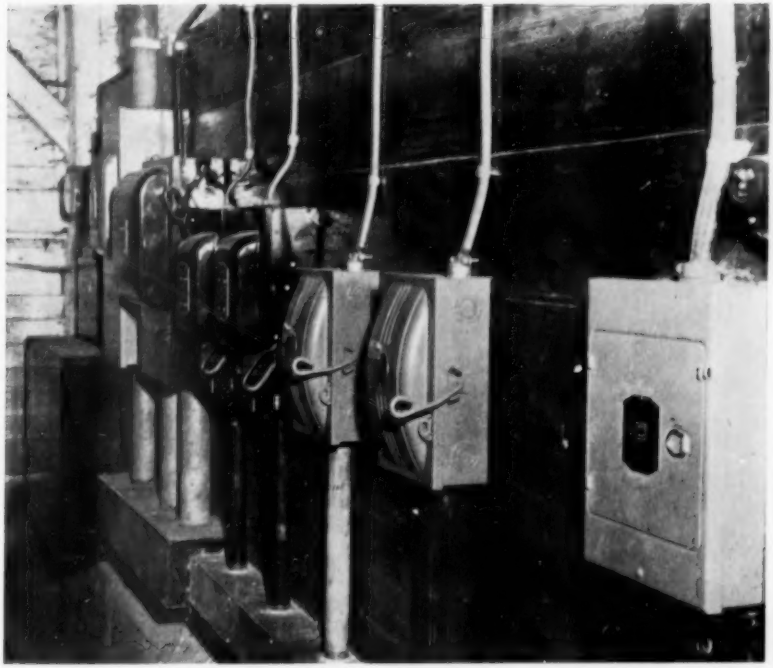


Figure 35. An example of service installation without a main switch (N.E. Code, Sec. 2351a) Service is 400 ampere. First switch is 200 ampere, for feeder to residence, tenant house, and 3-horsepower irrigating pump. Second switch is 100 ampere for milkhouse and barn load, including combination switch at extreme right. Third, fourth, fifth, and sixth switches are 50 ampere (fused at 30 amperes with time-delay fuses) for 5-horsepower hay driers

Service-entrance wires or cable are the portion of the conductors attached to the side of a building between the service "drop" wires and the service switch (figure 23).

The service switch (figures 33 to 37) provides a way to disconnect all the circuits of the building or all buildings from the source of supply.

It is through the service entrance that electricity is supplied to a building in such a way that it may be further distributed to various outlets for use as heat, light, and power.

The recommended minimum wiring practices for various buildings should be outlined at this time to determine the possible total requirements of the system. To calculate the size of feeder wires and the main service entrance, it is necessary to know the total connected or computed load and the probable maximum demand of each building.

Minimum Wiring for a Dairy Barn

Outlets

Lighting

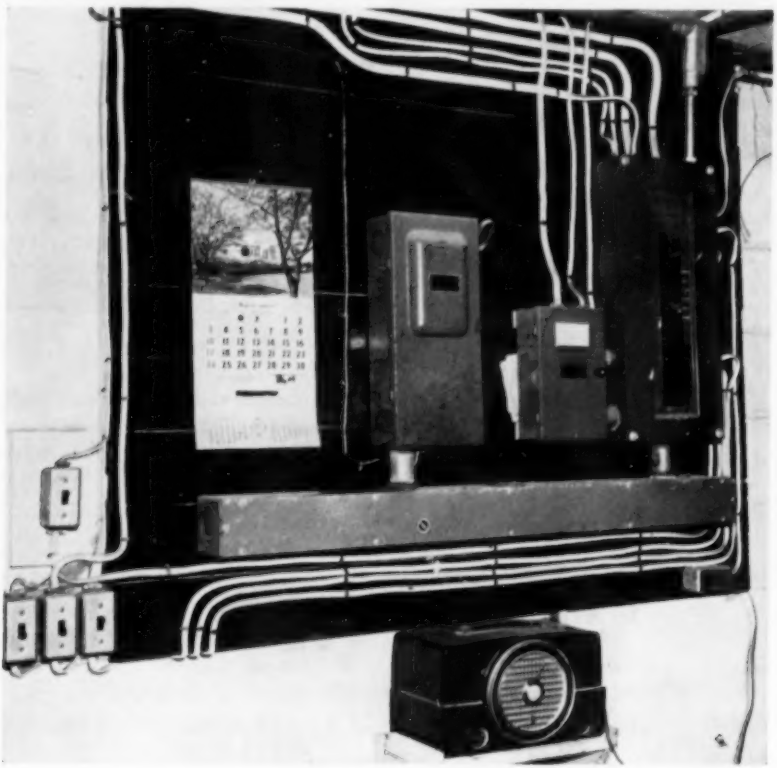
Litter alley

1 outlet with 100-watt lamp every 2 to 3 stalls or every 12 feet—switch-controlled circuit.

Feed alley

1 outlet with 100-watt lamp every 15 to 20 feet—switch-controlled circuit.

Figure 36. 200-ampere service, showing disconnect switch on the left and circuit breaker panel on the right



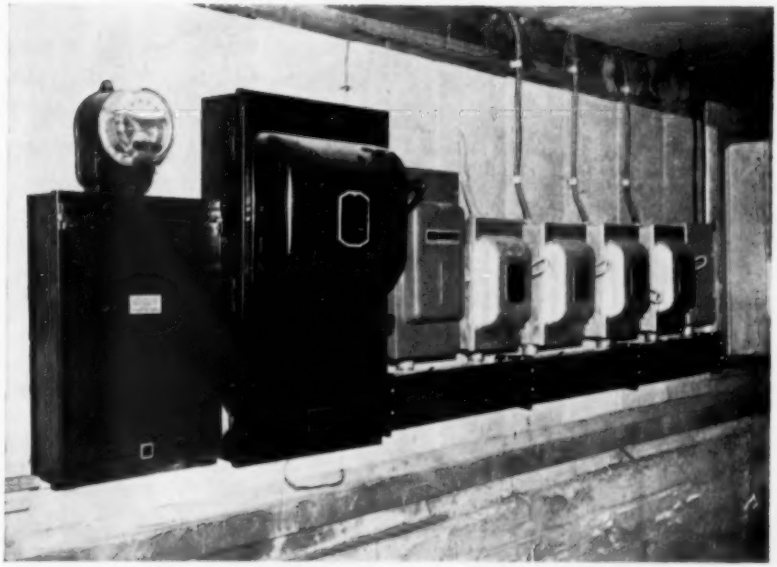


Figure 37. 200-ampere service in dairy barn
Separate switches for hay finisher, milkhouse feeder, farm shop feeder, residence feeder, and gutter cleaner. Fuse panel for other barn equipment and 200-ampere disconnect switch

Box stalls

1 outlet with 100-watt lamps for high-partitioned stall or 1 outlet between every 2 low-partitioned stalls. May be on feed alley circuit or separate switch-controlled circuit.

Milk house

1 outlet for each 100 square feet of floor area for general lighting

A minimum of 1.5 to 2 watts per square foot is recommended.

At least a 150-watt lamp in a suitable diffusing glass should be used over utensil-washing and sterilizing area.

Two lights are recommended for a bulk-cooler installation to illuminate the inside of the tank.

One exterior outlet for illuminating loading platforms and drive. All lighting outlets should be switch-controlled.

Hay mow

1 outlet for each 400 square feet of floor space, with at least one outlet for each hay mow—switch-controlled circuit or circuits. Dust-proof fixtures are recommended.

Drive floor

At least 2 outlets, 1 inside the barn for each 400 square feet of floor area, and 1 yard light at entrance to barn—switch-controlled circuit.

Silo and silo entrance

1 outlet on ceiling of each silo, 1 in each chute, and 1 in silage room—all 100-watt lamps—switch-controlled circuit.

Feed room

1 outlet for each feed room. For feed rooms of more than 400 square feet of floor area, 1 outlet for each 400 square feet or fraction thereof—all outlets switch-controlled. Dust-proof fixtures are required.

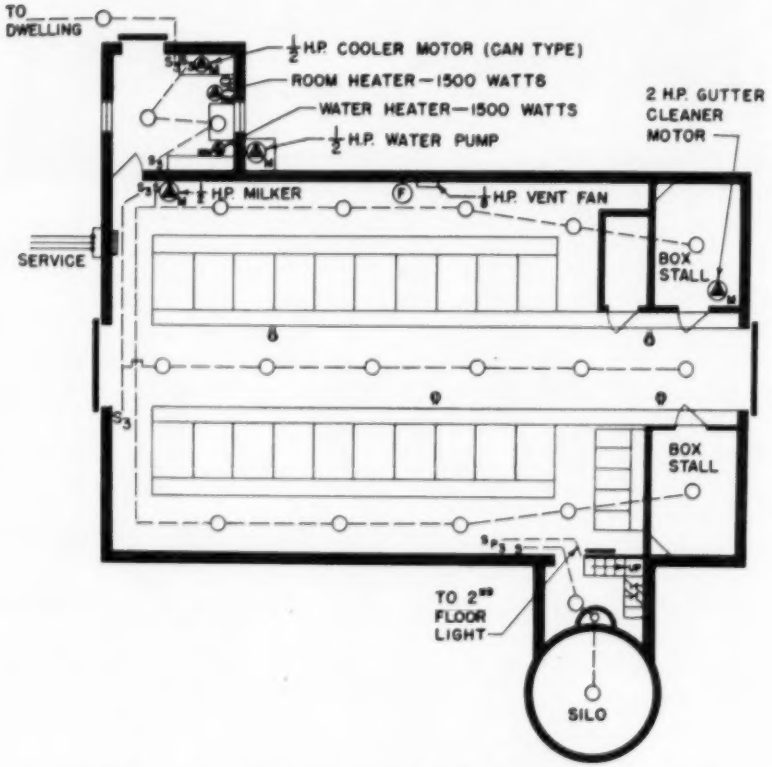


Figure 38. Ground-floor plan of a 20-cow dairy barn, showing the number, type, and location of the outlets and electrical equipment and the arrangement of the switches

Feed-grinding room

1 outlet for each 150 square feet of floor area—wall-switch controlled—also other outlets as needed over work areas. Dust-proof fixtures are required.

Convenience outlets

No. 12 wire is the minimum size recommended for all convenience-outlet circuits.

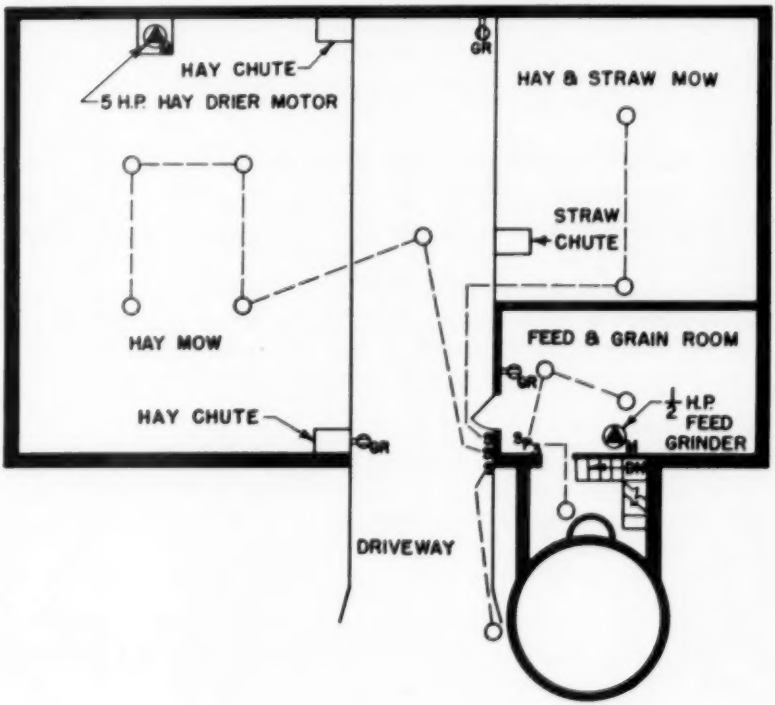
Litter alley

1 outlet every 20 feet for use of clippers, radios, and other portable equipment.

Box stall

1 outlet for each pen for use of heaters, clippers, and groomers, installed out of the reach of animals.

Figure 39. Second-floor plan of a 20-cow dairy barn, showing the number, type, and location of the outlets, the electrical equipment, and the arrangement of the switches



Work area

1 outlet in each work area in the barn.

Milk house

1 grounding type outlet for each work area in the milk house.

Drive floor

1 outlet for each 500 square feet of floor area for portable drills, lights, and small equipment, with a minimum of one grounding type outlet on each end of the drive floor.

Feed room and feed grinding room

1 grounding type outlet for each work area.

Special-purpose

Outlets for the milker motor, electric fan, milk cooler, water heater, feed grinder, hay drier, silo unloader, or elevator motor are classified as special-purpose outlets. These outlets are of a permanent nature and are usually used for a single purpose. The number of special-purpose outlets in a dairy barn depends on the equipment and appliances in that particular barn. The actual problem of using the previous information may be illustrated by calculating the load of a dairy barn (figures 38 and 39).

Wiring for a 20-cow dairy barn, 36 feet by 72 feet

The wiring problem may be considered as (1) computed load, (2) probable maximum demand, (3) size of service entrance, and (4) service switch.

The total computed load determines the minimum size of wire permissible in the service entrance and also influences the size of service switch. The probable maximum demand is used to determine the size of the feeder wires to serve the building under consideration.

Total computed load

The computed load is the total load that would be placed on a wiring system if all lights and equipment were in operation at one time, calculated according to requirements of the National Electrical Code.

Outlets

Lighting

2 yard lights, 2 milk house, 6 litter alley, 8 feed alley, 2 box stalls, 1 silo, 1 silo chute, 1 silo room, 6 hay mow, 1 service area, 2 feed and grain room and 1 drive. *Total lights 33*

Convenience

1 milk house, 2 box stalls, 2 litter alley, 2 drive floor, 1 feed room
Total convenience outlets 8[2]

41 outlets at 1.5 amperes per outlet at 115 volts	= 61.5 amperes	or 30.8 amperes at 230 volts
5-horsepower hay-drier motor	230 volts = 28.0 amperes	at 230 volts
2-horsepower gutter-cleaner	230 volts = 12.0 amperes	at 230 volts
½-horsepower milker motor	230 volts = 3.7 amperes	at 230 volts
½-horsepower milk-cooler motor	230 volts = 3.7 amperes	at 230 volts
½-horsepower water-pump motor	230 volts = 3.7 amperes	at 230 volts
½-horsepower feed-grinder motor	230 volts = 3.7 amperes	at 230 volts
⅛-horsepower ventilating fan at 115 volts	= 2.8 amperes = 1.4 amperes	at 230 volts
1500-watt room heater	230 volts = 6.5 amperes	at 230 volts
1500-watt water heater	230 volts = 6.5 amperes	at 230 volts
Computed load		100.0 amperes at 230 volts
Computed load + 25 per cent of largest motor[3]		7.0 amperes at 230 volts
Total computed load		107.0 amperes at 230 volts

Probable maximum demand

Probable maximum demand is the total load of lights and equipment that would likely be placed on the wiring system at one time.

5-horsepower hay-drier motor	28.0 amperes at 230 volts
2-horsepower gutter-cleaner motor	12.0 amperes at 230 volts
½-horsepower milker motor	3.7 amperes at 230 volts
½-horsepower milk cooler	3.7 amperes at 230 volts
1500-watt water heater	6.5 amperes at 230 volts
750-watt lighting	3.3 amperes at 230 volts
Computed load for maximum demand	57.2 ampers at 230 volts
Computed load for maximum demand + 25 per cent largest motor	7.0 amperes at 230 volts
Total computed load for probable maximum demand	64.2 amperes at 230 volts

Size of service-entrance wires

Service-entrance wires are normally on the side of the building, extending from the point of attachment of the service drop or feeder wires down to the service switch. They are seldom so long that the voltage drop needs to be considered if they are large enough to carry the total

[2] Required by National Electrical Code to determine total computed load.
[3] The National Electrical Code requires that 125 per cent of the running current of the largest motor be used in calculating the total connected load for selecting size of entrance wire.

computed load. For a total computed load of 107 amperes, the Code requirements are met by No. 2 type RH or No. 1 type TW wire (table 2, page 14).

Service-entrance switch

The service-entrance switch disconnects all wiring in the building from the source of supply. It usually includes the main fuses or circuit breaker where a single switch is used. This switch must be large enough to carry the total computed load in the building, plus the computed load in any other buildings served from the building in which the switch is located. Under certain conditions, more than one switch may be used (figures 34 to 37).

In addition, the switch must also carry the starting amperage of the largest motor. The running current of a motor is figured in the computed load. It is now necessary to add to the computed load (*not* total computed load) 200 per cent as follows: The largest motor has already been computed at 100 per cent in this computed load, therefore, the addition of 200 per cent will satisfy the requirements of National Electrical Code.[4]

Total computed load	100 amperes at 230 volts
Add 5 horsepower motor,	
28 amperes at 200 per cent	56 amperes at 230 volts
	156 amperes at 230 volts

This would require a 200-ampere switch fused at 150 amperes. While this appears to be over-fusing the service wires designed to carry around 115 amperes, it is covered by Section 2203f and 4314 of the National Electrical Code.

Should any other buildings be served through feeders from the barn, the computed loads in these buildings would have to be included in the calculations for size of service equipment.

Some of the common types and sizes of service switches are shown in figures 33 to 37.

[4] The National Electrical Code requires that a branch-circuit fuse shall be capable of carrying the starting current of a motor connected to the circuit and that a fuse protecting a group of motors must be capable of carrying the starting current of the largest motor of the group plus the full-load current of all other motors. In determining the size of fuse within these limits, its capacity *may not* exceed 300 per cent of the full-load current of the largest motor plus 100 per cent of the full-load current of other motors. It may be of smaller capacity if it is of a type that will permit the motor to start. Time-delay fuses are not mentioned in this connection but generally would be approved.

Wiring for a Dairy Barn, 36 feet by 180 feet

Many dairymen operate larger farms, so an example of a dairy-cow barn 36 feet by 180 feet (figures 40 and 41) serves to illustrate the wiring problem.

Total computed load (page 34).

Outlets

Lighting

2 yard lights, 3 milk house, 1 grain room, 2 feed storage, 3 service room, 15 litter alley, 18 feed alley, 1 stairs, 2 silos, 2 silo chutes, 1 silo room, 14 hay mows, 2 drive floor, 6 box stalls. *Total lights 72.*

Convenience

1 milk house, 2 service room, 1 grain room, 1 feed storage, 2 drive floor, 7 litter alley, 6 box stalls. *Total convenience outlets 20.*

Total outlets 92 at 1.5 amperes or 138 amperes at 115 volts or 69.0 amperes at 230 volts

5-horsepower hay-drier motor	28.0 amperes at 230 volts
5-horsepower hay-drier motor	28.0 amperes at 230 volts
5-horsepower gutter cleaner	28.0 amperes at 230 volts
5-horsepower silo unloader	28.0 amperes at 230 volts
3-horsepower bulk-milk cooler	17.0 amperes at 230 volts
2-horsepower feed grinder	12.0 amperes at 230 volts
1-horsepower bulk-milk-tank truck-pump motor	6.5 amperes at 230 volts
¾-horsepower hay elevator	5.1 amperes at 230 volts
1½-horsepower milker motor	9.2 amperes at 230 volts
1-horsepower water pump	6.5 amperes at 230 volts
2—½-horsepower ventilating fans at 115 volts = 10.2 amperes	5.1 amperes at 230 volts
½-horsepower bulk-milk-cooler circulator	2.6 amperes at 230 volts
¼-horsepower milk-cooler agitator	2.3 amperes at 230 volts
2000-watt room heater	8.7 amperes at 230 volts
2000-watt water heater	8.7 amperes at 230 volts
Computed load	264.7 amperes at 230 volts
Computed load + 25 percent of largest motor[5]	7.0 amperes at 230 volts
Total computed load	271.7 ampers at 230 volts

[5] If two or more motors of equal horsepower rating are the largest in the group, one of these should be considered as the largest for the above calculations.

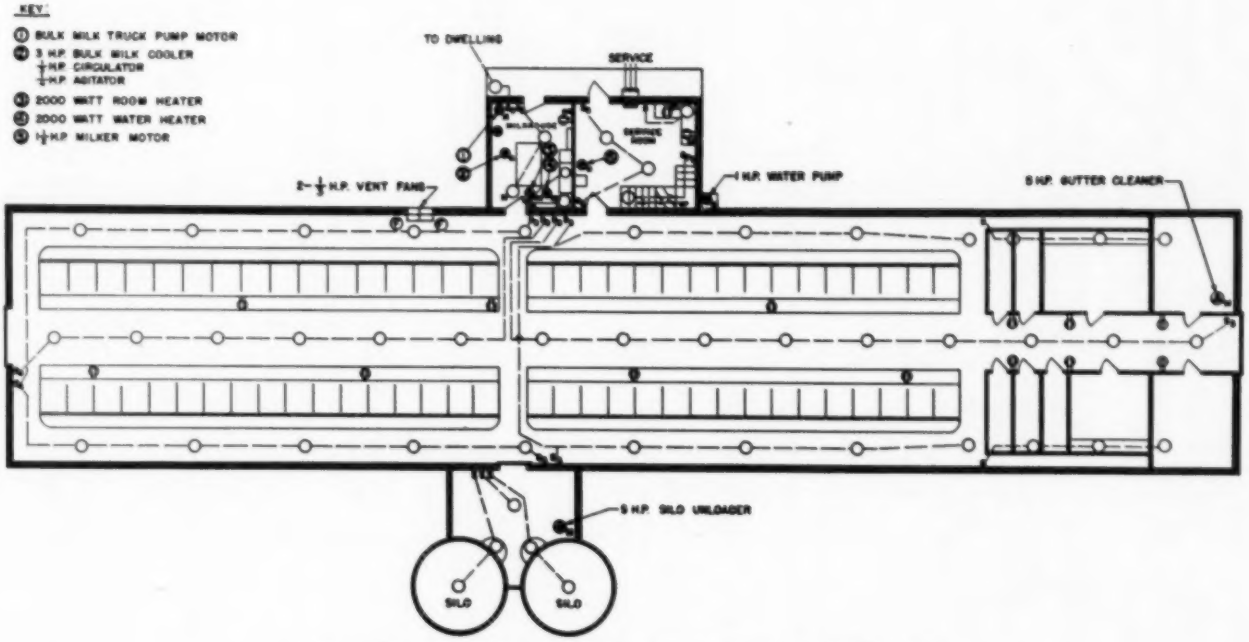


Figure 40. Ground floor plan of a 64-cow dairy barn, showing the number, type, and location of the outlets, the electrical equipment, and the arrangement of the switches

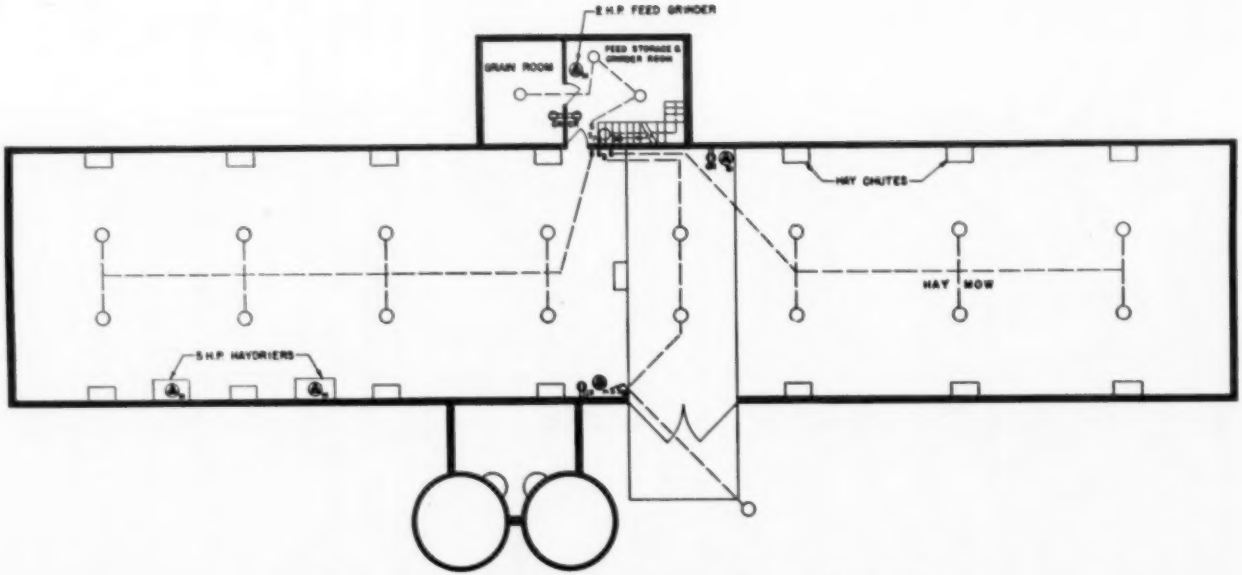


Figure 41. Second-floor plan of a 64-cow dairy barn showing the number, type and the location of the outlets, electrical equipment, and the arrangement of switches

Probable maximum demand

Two 5-horsepower hay driers at 28 amperes=	56.0 amperes at 230 volts
5-horsepower gutter cleaner	28.0 amperes at 230 volts
1½-horsepower milker	9.2 amperes at 230 volts
3-horsepower milk cooler	17.0 amperes at 230 volts
1-horsepower water pump	6.5 amperes at 230 volts
2000-watt water heater	8.7 amperes at 230 volts
2000-watt lighting	8.7 amperes at 230 volts
Computed load of maximum demand	134.1 amperes at 230 volts
Total computed load of maximum demand + 25 percent of largest motor	7.0 amperes at 230 volts
Total computed load for probable maximum demand	141.1 amperes at 230 volts

Size of service-entrance wires

For a total computed load of 271.7 amperes, it is necessary to use 400 M.C.M. type TW or 300 M.C.M. type RH.

Service-entrance switch

This service is computed the same as previously.

Computed load	264.7 amperes at 230 volts
5-horsepower motor at 200 per cent	56.0 amperes at 230 volts
	320.7 amperes at 230 volts

One switch of 400-ampere capacity with 350-ampere fuses would be satisfactory. While this appears to be over-fusing the service wires designed to carry around 285 amperes, it is covered by Section 2203F and 4314 of the National Electrical Code.

Alternate possibilities would be two 200-ampere switches fused for a total of 325 amperes; or one 200-ampere "combination" switch fused at 150 amperes, four 60 ampere switches with 30-ampere time-delay fuses, and one 30-ampere switch with 20 ampere time-delay fuse.

The size of feeder wires, main service entrance, and circuits are discussed on pages 53 to 63.

Minimum Wiring for a Poultry and Brooder House

Outlets

Lighting

1 outlet with a 40- or 60-watt lamp with a wide reflector, or a 60- or 75-watt lamp with built-in reflector, or a 100-watt lamp without a reflector, used for every 200 square feet of floor area

1 outlet in the feed room
1 outlet for every 200 square feet of floor area in egg storage and grading room, with additional outlets over each work area
1 outlet for each individual brooder house or for each 200 square feet of floor area of permanent type house
1 outlet in each passageway and stairs
1 outlet with 10-watt lamp for every 400 square feet of floor area for dim-light lighting if used
1 outlet for each 200 square feet of service and storage room
1 outlet for boiler room
1 outlet for each work area

Convenience

1 outlet for every 800 square feet of floor space, with at least:
1 outlet for every pen for laying or brooder house
1 outlet in egg-grading and handling room for egg grader
1 outlet in any work area in the building
1 outlet in egg storage room for egg pre-cooler and cooler
1 outlet in egg storage room for humidifier

Special-purpose

1 outlet for elevator in multi-story house
1 outlet for platform hoist in multi-story house
1 outlet for room heater if used
1 outlet for egg washer
1 outlet for circulating pump and heater element
1 outlet for egg-room cooler if wired for 230 volts or more than ½ horsepower
1 outlet for ventilating fan or fans
1 outlet for each automatic poultry feeder
1 outlet for circulating pumps
1 outlet for 230 volts for feed-grinding
1 outlet for water heater

Wiring for a Large Poultry House

An example to illustrate the practices and recommendations previously outlined could be the wiring problem of a two-story poultry house 48 feet by 172 feet (figures 42 and 43).

Total computed load

Lighting

Ground floor—37 pen lights, 1 egg storage, 2 grading room, 2 feed room (service area), 1 stairs, 1 yard	(44)
Second floor—39 pen lights, 2 service room	(41)
Total lights	85

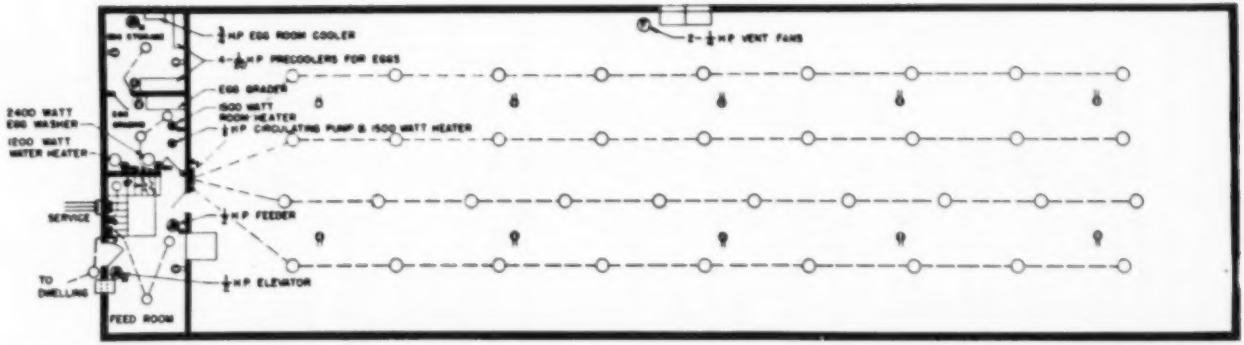


Figure 42. Ground floor plan of a two-story, 2400-bird poultry house, showing the number, type, and location of outlets, the electrical equipment, and the arrangement of the switches

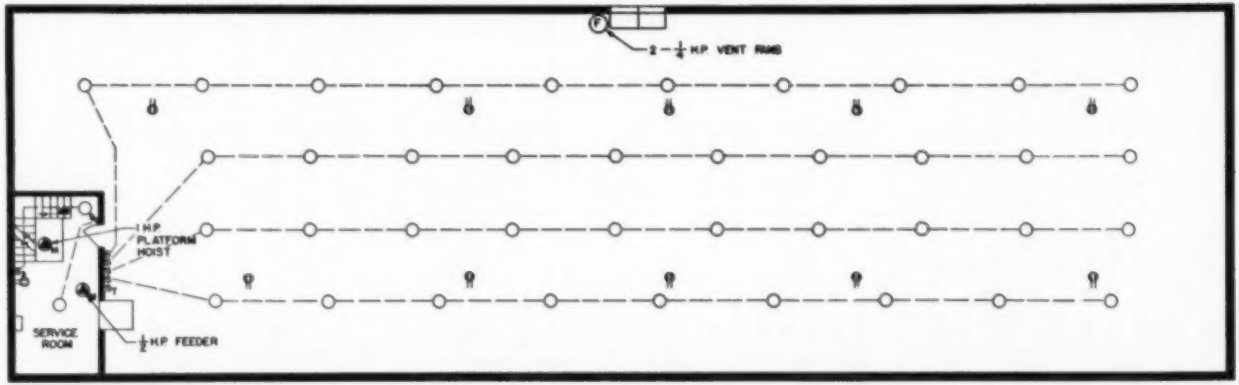


Figure 43. Second-floor of a two-story, 2400-bird poultry house, showing the number, type, and location of the outlets, the electrical equipment, and the arrangements of the switches

Convenience

Ground floor—10 pen outlets, 1 feed service area, 1 egg grading, 3 egg storage	(15)
Second floor—10 pen outlets, 1 feed-service area	(11)
Total convenience outlets	26

85 light outlets × 1.0 amperes[6] =	85.0 amperes at 115 volts
26 convenience outlets at 1.5 amperes =	39.0 amperes at 115 volts
4—¼-horsepower vent fans (4.6 amps each)	18.4 amperes at 115 volts
½-horsepower elevator	7.4 amperes at 115 volts
2—½-horsepower feeders (7.4 amperes × 2)	14.8 amperes at 115 volts
1-horsepower hoist	13.0 amperes at 115 volts
⅙-horsepower circulating pump, 2.8 amperes + 1500-watt heater (13.0 amperes)	15.8 amperes at 115 volts
¾-horsepower cooler	10.2 amperes at 115 volts
1200-watt water heater	10.4 amperes at 115 volts
2400-watt egg washer	20.8 amperes at 115 volts
1500-watt room heater	13.0 amperes at 115 volts
Computed load	247.8 amperes at 115 volts
Computed load + 25 per cent of largest motor	3.3 amperes at 115 volts
Total	251.1 amperes at 115 volts
Total computed load	*125.6 amperes at 230 volts*

Probable maximum demand

85 lights at 1.0 amperes	85.0 amperes at 115 volts
1200-watt water heater	10.4 amperes at 115 volts
2400-watt egg washer	20.8 amperes at 115 volts
1500-watt room heater	13.0 amperes at 115 volts
Circulator and heater	15.8 amperes at 115 volts
Two ½-horsepower feeders (7.4 amperes)	14.8 amperes at 115 volts
Four 1/20-horsepower pre-cooler motor (2.4 amperes)	9.6 amperes at 115 volts
Four ¼-horsepower vent fans at 4.6 amperes	18.4 amperes at 115 volts
One ¾-horsepower cooler motor	10.2 amperes at 115 volts
Computed load	198.0 amperes at 115 volts
Computed load + 25 per cent of largest motor	2.6 amperes at 115 volts
Total	200.6 amperes at 115 volts
Total computed load for probable maximum demand	*100.3 amperes at 230 volts*

[6] The National Electrical Code requires that in calculating total connected load, 1.5 amperes be used for each light outlet. Poultry lighting outlets will, however, not average more than 1 ampere each.

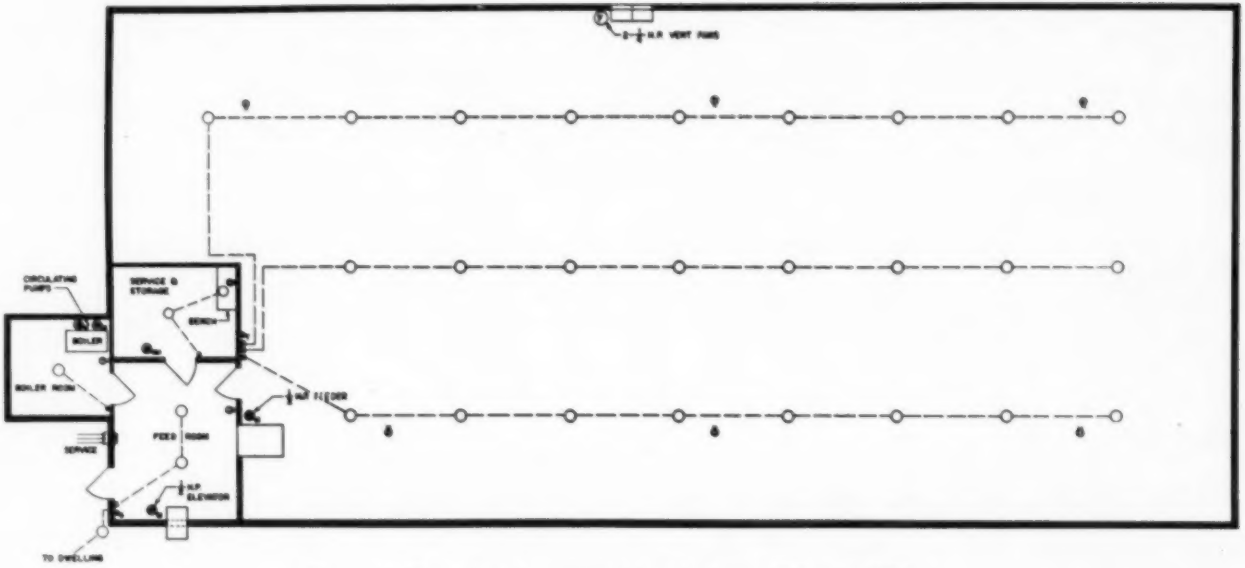


Figure 44. Floor plan of permanent brooder house 48 feet by 108 feet

Most of the equipment may be on at one time. This is to be expected in a poultry house during the period of shorter daylight hours.

Size of service-entrance wires

For a total computed load of 125.6 amperes at 230 volts, No. 0 type TW or No. 1 type RH wire would be required. This would not allow for any future expansion. The practical approach would be to use at least No. 0 type RH or equivalent.

Service-entrance switch

This is computed the same as in previous examples.

Computed load	123.9 amperes at 230 volts
+ 200 per cent of largest motor	13.0 amperes at 230 volts
Total	136.9 amperes at 230 volts

A 200-ampere switch fused at 150 amperes or two 100-ampere "combination" switches fused for a total of 150 amperes would meet the requirements.

Wiring for a Permanent Brooder House

An example of a brooder house will further illustrate the wiring problem. A house 48 feet × 108 feet (figure 44) will serve as an example.

Total computed load

Outlets

Lighting

25 pen lights, 1 boiler room, 2 service and storage room, 2 feed room, 1 yard light. *Total lights 31.*

Convenience

6 pen outlets, 1 feed room, 1 service and storage room, 1 boiler room. *Total convenience outlets 9.*

31 lights at 1.0 amps	=	31.0 amperes at 115 volts
9 convenience outlets at 1.5		13.5 amperes at 115 volts
Two ¼-horsepower ventilating fans at 4.6 amperes each		9.2 amperes at 115 volts
One automatic-feeder motor (½-horsepower)		7.4 amperes at 115 volts

Two ⅓-horsepower circulator motors at 5.1 amperes each	10.2 amperes at 115 volts
One ½-horsepower boiler motor	7.4 amperes at 115 volts
One 1500-watt water heater	13.0 amperes at 115 volts
One ½-horsepower elevator	7.4 amperes at 115 volts
Computed load	99.1 amperes at 115 volts
+ 25 per cent largest motor	1.9 amperes at 115 volts
	101.0 amperes at 115 volts
	or
Total computed load	*50.5 amperes at 230 volts*

Probable maximum demand

29 lights at 1.0 amperes	29.0 amperes at 115 volts
Two ¼-horsepower fans at 4.6 amperes	9.2 amperes at 115 volts
One ½-horsepower automatic-feeder motor	7.4 amperes at 115 volts
Two ⅓-horsepower circulator motors (5.1 amperes)	10.2 amperes at 115 volts
One ½-horsepower boiler motor	7.4 amperes at 115 volts
Computed load	63.2 amperes at 115 volts
+ 25 per cent of largest motor	1.9 amperes at 115 volts
Total	65.1 amperes at 115 volts
Total computed load for probable maximum demand	*32.6 amperes at 230 volts*

Size of service-entrance wires

For a computed load of 50.5 amperes, it is necessary to use No. 6 type RH or type T conductors.

Service-entrance switch

This switch is computed the same at previously.

Computed load	99.1 amperes at 115 volts
Add ½-horsepower motor, 7.4 amperes at 200 per cent	14.8 amperes at 115 volts
Total	113.9 amperes at 115 volts
	or
	56.9 amperes at 230 volts

This switch must be a minimum of 60 amperes. A combination 60-ampere switch of the type having 100-ampere main lugs, and with the "range" and main lighting fuses in parallel or multiple would, however, seem advisable to allow for future expansion.

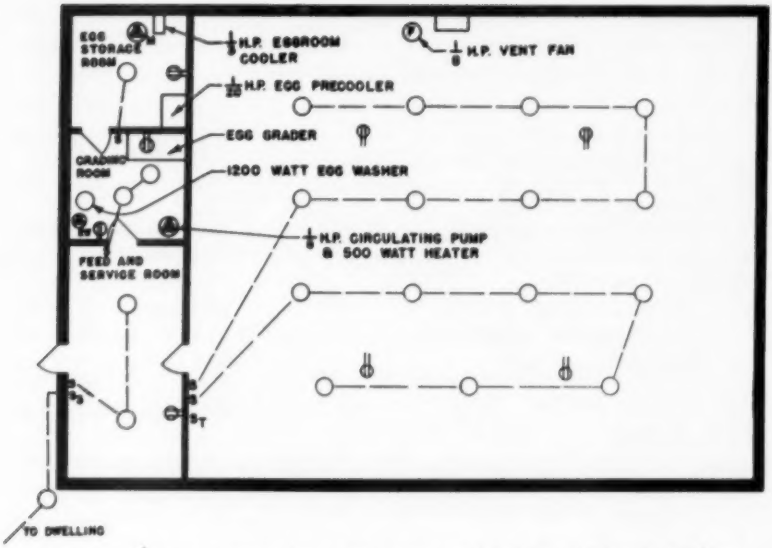


Figure 45. Wiring diagram for a single-story poultry house 48 feet by 72 feet

Wiring for a Poultry House 48 feet by 72 feet and a Brooder House 12 feet by 16 feet

An example of a small poultry house and a brooder house illustrates the wiring problem for a smaller operator (figures 45 and 46).

Total computed load

Lighting

15 pen lights, 2 feed and service room, 2 grading room, 1 egg storage, 1 yard light. *Total lights 21.*

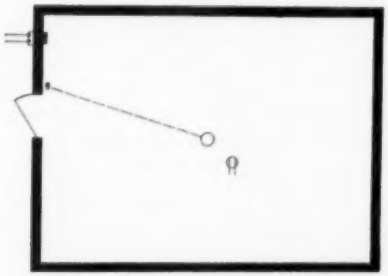


Figure 46. Colony-type brooder house, showing light and convenience outlets

Convenience

4 pen outlets, 1 feed and service room, 2 grading room, 1 egg storage room. *Total convenience outlets 8.*

21 light outlets × 1.0 amperes	21.0 amperes at 115 volts
8 convenience outlets at 1.5 amperes	12.0 amperes at 115 volts
1200-watt egg washer	10.4 amperes at 115 volts
⅛-horsepower motor + 500-watt heating element (4.4 amperes)	7.2 amperes at 115 volts
⅛-horsepower ventilating fan	2.8 amperes at 115 volts
⅓-horsepower egg cooler	5.1 amperes at 115 volts
Computed load	58.5 amperes at 115 volts
+ 25 per cent largest motor	1.3 amperes at 115 volts
Total computed load	*59.8 amperes at 115 volts* or *29.9 amperes at 230 volts*

Brooder house

Lighting 1 at 1.0	1.0 amperes at 115 volts
Convenience 1200 watts	10.4 amperes at 115 volts
Computed load	*11.4 amperes at 115 volts* or 5.7 amperes at 230 volts
Total computed load (house and brooder)	*35.6 amperes at 230 volts*

Probable maximum demand

Lights

15 pen lights, 2 grading room, 2 service, or a total of 19 lights at 1.0 amperes	19.0 amperes at 115 volts
1200-watt egg washer	10.4 amperes at 115 volts
⅛-horsepower ventilating fan	2.8 amperes at 115 volts
1/20-horsepower egg precooler	2.4 amperes at 115 volts
⅓-horsepower egg cooler	5.1 amperes at 115 volts
1/20-horsepower egg grader	2.4 amperes at 115 volts
⅛-horsepower motor (2.8 amperes) + 500 watt heating element (4.4 amperes)	7.2 amperes at 115 volts
1200-watt brooder	10.4 amperes at 115 volts
Computed load	59.7 amperes at 115 volts
+ 25 per cent largest motor	1.3 amperes at 115 volts
	61.0 amperes at 115 volts or
Total computed load for probable maximum demand	*30.5 amperes at 230 volts*

This load is to be expected in a poultry house during the period of doing chores.

Size of service-entrance wires

If these buildings were served from a meter pole and thus had a service entrance within the National Electrical Code definition, section 2304a would apply, which requires not less than No. 6 conductor in installations consisting of more than two branch circuits. This poultry house would require, at least, two No. 6's, but good practice would call for a three-wire service. If these buildings were served by a 3-wire feeder from another building, then for 35.6 amperes, 115 and 230 volts, 3 No. 8's in the service cable would pass.

Wiring for a Residence

The residence is a part of the farm wiring system. While the detailed requirements of the house are not given in this bulletin, the essentials necessary to compute the computed load, the probable maximum demand, the size of the service, and the service switch are given.

These are computed in accordance with the National Electrical Code as follows:

Total computed load

House 30 by 40 feet = 1200 square feet × 2 floors = 2400 square feet	
Lighting load at 3-watts per square feet	= 7200 watts
Appliance load (2 circuits × 1500 watts)	= 3000 watts
Total	10,200 watts
First 3000 watts at 100 per cent	3,000 watts
Balance of 7200 watts at 35 per cent	2,520 watts
Net computed load with range and water heater	5,520 watts
12-kilowatt electric range[1]	8,000 watts
Water heater	2,000 watts
Drier	5,500 watts
Total computed load	*21,020 watts*

The load at 230 volts is 91.4 amperes at 230 volts

Probable maximum demand

It is assumed that a maximum of half of the lighting, half of the appliance load will be in use at any one time. In addition, at the same time, half of the range load, all the drier load, and the water heater load might be in use.

The maximum demand would be calculated as follows:

[1] National Electrical Code allows 8 kilowatts in calculating connected load for ranges rated at 12 kilowatts or less.

Lighting (50 per cent of 7200 watts)	3600 watts
Appliances (50 per cent of 3000 watts)	1500 watts
Range (50 per cent of 12,000 watts)	6000 watts
Drier load	5500 watts
Water heater	2000 watts
	18600 watts or
Total computed load for probable maximum demand	*80.9 amperes or 230 volts*

Size of service-entrance wires

For a computed load of 91.4 amperes, size No. 2 RH or T will be required.

Service-entrance switch

There are no large motor loads. Therefore, the service switch must handle the same load as the service-entrance conductors. This would require a 100-ampere "combination" switch, or the equivalent in a circuit breaker.

This switch or circuit breaker should have branch circuits for the range, water heater, clothes drier, appliance circuits, and light circuits.

Minimum Wiring for a Farm Shop

A shop 24 by 40 feet (figure 47) serves as an example to illustrate the minimum recommended practices to be followed in a farm shop.

Outlets

Lighting

1 outlet for every 200 square feet of floor area—wall-switch controlled circuit.

1 outlet for each permanently located piece of equipment, such as drill press and bench grinder—wall-switch controlled

1 outlet for each 10 feet of work bench—wall-switch controlled.

Convenience

1 outlet for each 10 feet of work bench

1 outlet for all permanently placed equipment of less than ½ horsepower

1 outlet at each main door for outside work

Special-purpose

1 outlet for each piece of motor-driven equipment of ½ horse power and more.

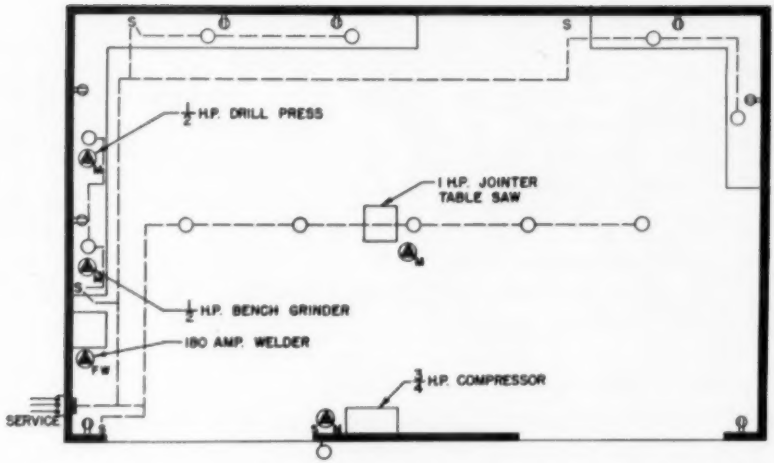


Figure 47. Floor plan of a farm shop, showing the number, type, and location of the outlets, the electrical equipment, and the arrangement of the switches

For motors of ½ horsepower and over, 230 volts is preferable.

A special outlet or outlets should be provided for the farm welder.

Total computed load

Lighting outlets		
5 room, 6 bench, 1 yard	(12)	
Convenience outlets	(8)	
Total	20 × 1.5 amperes = 30.0 amperes at 115 volts	
	or	
		15.0 amperes at 230 volts
¾-horsepower compressor		5.1 amperes at 230 volts
½-horsepower drill press		3.7 amperes at 230 volts
1-horsepower jointer (table saw)		6.5 amperes at 230 volts
½-horsepower grinder		3.7 amperes at 230 volts
Farm welder (180-ampere)		37.5 amperes at 230 volts
Computed load		71.5 amperes at 230 volts
Add 25 per cent largest motor		1.6 amperes at 230 volts
Total computed load		*73.1 amperes at 230 volts*

Probable maximum demand

Lights 800 watts	3.5 amperes at 230 volts
1-horsepower jointer	6.5 amperes at 230 volts
Welder	37.5 amperes at 230 volts
Computed load	47.5 amperes at 230 volts
Add 25 per cent largest motor	1.6 amperes at 230 volts
Total computed load for probable maximum demand	*49.1 amperes at 230 volts*

Size of service-entrance wires

For a computed load of 73.1 amperes, No. 4 type RH or No. 2 Type T will be required for this load.

Service-entrance switch

The National Electrical Code permits the use of overcurrent protection (fuses or circuit breakers) in a welder circuit rated at not more than 200 per cent of the primary or input current of the welder. A similar allowance would be permissible in the service of equipment.

Using this as a basis, the size of the service switch would be calculated as follows:

Computed load	71.5 amperes at 230 volts
Less largest motor, one horsepower (6.5 amperes)	6.5 amperes at 230 volts
	65.0 amperes at 230 volts
less welder	37.5 amperes at 230 volts
	27.5 amperes at 230 volts
Plus largest motor, 1 horsepower (6.5 amperes at 300 per cent)	19.5 amperes at 230 volts
Plus welder at 200 per cent	75.0 amperes at 230 volts
Total computed load	*122.0 amperes at 230 volts*

This would call for a 200-ampere switch with 125-ampere fuses or a 100-ampere "combination" switch with 75-ampere fuses for the welder and a 60-ampere switch with 50-ampere fuses for the remainder of the equipment. It is likely that if a circuit breaker were used, a 100-ampere breaker would have enough time-delay to prevent tripping the breaker when the welder would be in use.

With fuses of the time-delay type, a combination switch with 100-ampere main lugs and main and "range" fuses in parallel could be used. The range-fuse position could be equipped with 40-ampere time-delay fuses for the welder circuit, while 50-ampere fuses would protect the remainder of the equipment.

Feeder Wires to Buildings

The size of the service, the total computed load, and the probable maximum demand for the various farm buildings have been calculated. The next problem is the size of feeder wires. Feeder wires are the conductors that provide a path for electricity to flow between buildings or from the meter pole to buildings being served (figure 48).

Feeder wires may be compared to water-pipe lines. If the size of the wires or pipes are too small or the length too great or both, water or power available at the point of use is inadequate.

It has been previously shown that a drop in voltage causes a loss in light, power, and heat. Therefore, it is essential to keep the loss on feeder wires to a minimum.

Pole-Service

An actual problem serves to illustrate the size of feeder wires necessary to insure adequate voltage at the various buildings. A pole-metering service with feeder wires to buildings is illustrated in figure 48. The farmstead illustrated (pages 55 and 56) has the residence (page 49), a 36-by-72-foot 20-cow dairy barn (pages 34 to 36), a two-story 48-by-72-foot poultry house (pages 41 to 45), a 48-by-108-foot brooder house (page 45), and a shop (page 50). The total computed loads and the probable maximum demands that have already been calculated are used for the load. The distances to each building are given.

In calculating the size of feeder wires, both total computed load, probable maximum demand, and voltage drop must be considered. The total computed load establishes the smallest wire size permitted by the National Electrical Code.

The Code requires that service wires be large enough to carry the current of the total computed load without a rise in temperature that would damage the insulation. The voltage drop to be expected with the probable maximum demand involves the demand, the distance, and the amount of voltage drop that can be allowed. Usually a maximum of 2 per cent voltage drop on a feeder wire is considered reasonable, except for feeders that supply brooders, incubators, or other equipment that is particularly sensitive to voltage drop and on which some life process depends. In such cases, the voltage drop on the feeder should be held to 1 per cent. An additional drop of 1 to 2 per cent may be expected on branch circuits, as indicated on pages 25 and 26 under section concerning carrying capacity of circuits.

The residence has a total computed load of 91 amperes, a probable maximum demand of 81 amperes at 230 volts, and a distance of 125

feet. In the last two columns of table 2 (page 14) the smallest size wire permissible for a total computed load of 91 amperes is weatherproof No. 6 (WP). In table 9 (page 69) for a probable maximum demand of 81 amperes, a voltage drop of 2 per cent and a distance of 125 feet, No. 2 wire is required. Therefore, the feeder should have two No. 2 weatherproof wires, while the neutral could safely be No. 6 weatherproof since the water heater, clothes drier, and part of the range load is straight 230-volt load, not connected to the neutral.

The dairy barn has a total computed load of 107 amperes, a probable maximum demand of 64 amperes and a distance of 190 feet. In table 2 (page 14), the smallest size of weatherproof wire permissible for a total computed load of 107 amperes is No. 4 (WP). For a probable maximum demand of 64 amperes, a distance of 200 feet and a 2 per cent voltage drop, No. 2 wire is required (table 9, page 69). Hence, the final determination of this feeder will be two No. 2 weatherproof and a No. 4 weatherproof neutral wire.

Before determining the size of the neutral wire, one can omit all straight 230-volt loads not connected to the neutral. This eliminates at least all motors of 1 horsepower or larger, and the water heater. To satisfy the minimum requirements of the Code, then, two No. 4's and one No. 6 weatherproof wires are needed, but to keep voltage drop within reasonable limits, the two No. 2's and the one No. 4 should be used.

The poultry house has a total computed load of 126 amperes, a probable maximum demand of 100 amperes, and a distance of 140 feet. No. 4 WP wire is required as a minimum for a total computed load of 126 amperes (table 2, page 14). To carry a probable maximum demand of 100 amperes, 150 feet with 2 per cent voltage drop requires No. 1 wires (table 9, page 69).

Since approximately 35 amperes of this load will be on 230 volts, the neutral would carry approximately 65 amperes. This would require No. 2 wire (table 9, page 69). Therefore, the feeder wires would be 2 No. 1's WP and 1 No. 2 WP.

The shop has a total computed load of 73 amperes, a probable maximum demand of 49 amperes, and is 115 feet from the meter pole. In table 2 (page 14), No. 6 WP would be the minimum permissible size of conductor to comply with the Code. To carry a probable maximum demand of 49 amperes, 125 feet, with a 2 per cent voltage drop No. 4 wire is needed (table 9, page 69).

Since the welder is a straight 230-volt device and puts no load on the neutral wire, the total computed load on the neutral can be reduced by at least 37.5 amperes leaving 35 amperes. No. 10 weatherproof wire

would carry this load safely; but for spans more than 50 feet, No. 8 is the smallest wire permissible. However, 35 amperes at a distance of 125 feet would require No. 6 wire (table 9, page 69). Therefore, the neutral wire will be No. 6 WP, the same as Code and 2, No. 4 WP, for the two "hot" feeder wires.

The brooder house has a total computed load of 51 amperes and a probable maximum demand of 33 amperes and a distance of 400 feet.

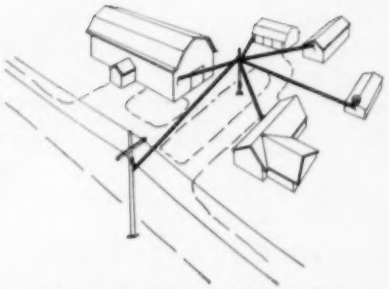


Figure 48. Pole metering and power distribution to dwelling, dairy barn, farm shop, and poultry house

From table 2 (page 14) a total computed load of 50 amperes needs No. 10 weatherproof wire to carry this load safely, but for spans more than 50 feet, No. 8 is the smallest wire permissible by Code.

Figure 49. 200-ampere pole meter with three No. 6 service drop wires to the residence, and three No. 4 feeder wires to the barn, and three No. 6 feeder wires to the shop

Table 3. Wiring Needs for a Specific Farm—Pole Service

Building	Total computed load		Service-entrance wires* (type T)	Service switch	Probable maximum demand		Distance (pole to building)	Minimum allowable wire size* (WP) for total computed load	Wire size to carry probable maximum demand within desired voltage drop
	Amperes	*Volts*	*Number*	*Amperes*	*Amperes*	*Volts*	*Feet*	*Number*	*Number*
Dairy barn	107	230	3 No. 1	200	64	230	190	2 No. 4 1 No. 6	2 No. 2 1 No. 4
Residence	91	230	3 No. 2	100	81	230	125	2 No. 6 1 No. 8	2 No. 2 1 No. 6
Poultry house	126	230	3 No. 0	200	100	230	140	2 No. 4 1 No. 6	2 No. 1 1 No. 2
Brooder house	51	230	3 No. 6	60	33	230	400	3 No. 8	3 No. 2
Shop	73	230	3 No. 2	200	49	230	115	2 No. 6 1 No. 8	2 No. 4 1 No. 6

* In buildings, such as the dairy barn, residence, and shop, where large items of equipment are served by 230-volt circuits and are not connected to the neutral wire, most inspection authorities permit the neutral wire of the service entrance and the feeder wires between buildings to be one size smaller than the live or "hot" wires.

From table 9 (page 69) a probable maximum demand of 33 amperes for a distance of 400 feet, No. 2 wire is required. Without the motor loads, approximately 25 amperes will be carried on the neutral wire. No. 2 wire will still be required for this load at a distance of 400 feet (table 9, page 69). Therefore, the feeder wire to the brooder house would be 3 No. 2's, WP.

Table 3 on page 56 summarizes the information for the farm requirements for pole service.

This problem has illustrated that the minimum size of feeder wires which might meet the requirements of the National Electrical Code for the entire total computed load may not be large enough to carry a portion of this load within the desirable limits of voltage drop. It is, therefore, desirable to determine the size of feeder wires both from the standpoint of the Code and of desired voltage drop, and to select whichever size is the larger.

Metering on a Building

Placing the service entrance on one of the buildings, with the meter either indoors or outdoors, is another way to wire farm buildings. The size of feeder wires needed to insure adequate voltage at various buildings (figure 50) is shown in table 4. The same buildings and the same computed loads as for pole service are used to illustrate this type of wiring. The distances to each building are different from those in the previous problem, but the actual distances between buildings in this type of wiring system are given as needed in the problem. The main service is in the residence.

The residence has a total computed load of 91 amperes, and a probable maximum demand of 81 amperes at 230 volts. Since, however, the main service is in the residence, no separate feeder calculation is required for the residence alone. The size of service entrance must, however, be determined from the total computed load at the farm (page 61).

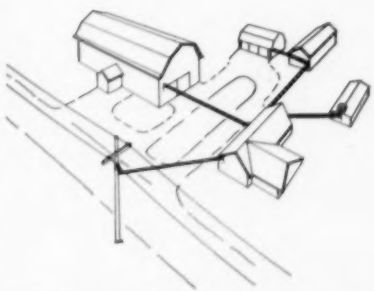


Figure 50. Indoor metering with feeder wires to outlying buildings

The dairy barn has a total computed load of 107 amperes, a probable maximum demand of 64 amperes at 230 volts. It is 265 feet from

Table 4. Wiring Needs for a Specific Farm—Metering on a Building

Building	Total computed load		Service-entrance wires† (type T)	Service switch	Probable maximum demand		Distance (length of feeder)	Minimum allowable wire size§, (WP) for total computed load	Feeder wire size for maximum demand within desired voltage drop
	Amperes	*Volts*	*Number*	*Amperes*	*Amperes*	*Volts*	*Feet*	*Number*	*Number*
Residence (plus all farm buildings)	448	230	†3–1000 M.C.M.	600	...	...	0	...	...
Dairy barn	107	230	3 No. 1	200	64	230	265	2 No. 4 1 No. 6	2 No. 0 1 No. 4
Poultry	126	230	‡3 No. 0	200	100	230	180	2 No. 1§ 1 No. 2	2 No. 00 1 No. 1
Brooder	51	230	3 No. 6	60	33	230	275	3 No. 8	2 No. 2 1 No. 4
Shop	73	230	3 No. 2	200	49	230	80	2 No. 6 1 No. 8	2 No. 6 1 No. 8

* In buildings, such as the dairy barn, residence, and shop, where large items of equipment are served by 230-volt circuits and not connected to the neutral wire, most inspection authorities permit the neutral wire of the service entrance and the feeder wires between buildings to be one size smaller than the live or "hot" wires.

† The service entrance must carry the total computed loads of all the buildings.

‡ The service feeders to the shop do not enter the poultry house.

§ Total computed load for minimum allowable wire size for poultry and shop is 199 amperes, with a combined probable maximum demand of 125 amperes.

the residence. The minimum permissible wire size for this total computed load is No. 4 WP wire. However, 64 amperes carried 275 feet require No. 0 wires (table 9, page 69).

Since approximately 54 amperes of the probable maximum demand will not be carried on the neutral, there is only 10 amperes to be carried. No. 8 wire will safely carry this load for 265 feet (table 9, page 69). Therefore, the design of the system will be 2 WP No. 0 and a No. 4 WP to comply with Code and desired voltage drop.

The brooder house has a total computed load of 51 amperes, a probable maximum demand of 33 amperes at 230 volts. It is 275 feet from the residence. The minimum permissible size of wire is No. 10 WP (table 2, page 14) except that in spans of more than 50 feet the Code would require No. 8 wire. Thirty-three amperes carried 275 feet would require No. 2 wire (table 9, page 69). However, 33 amperes less the larger motor, which will not be carried on the neutral, carried 275 feet will require No. 4 wire (table 9, page 69). The larger design of the system should be used. This is 2 No. 2's WP and 1 No. 4 WP.

The shop with a total computed load of 73 amperes carried at a distance of 80 feet requires No. 6 WP wire (table 2, page 14). A probable maximum demand of 49 amperes at 80 foot distance requires No. 6 wire (table 9, page 69). Since the neutral wire will not carry the 37.5 ampere load of the welder, approximately 12 amperes will be carried. This requires No. 12. wire (table 9, page 69). For spans of more than 50 feet, the Code requires No. 8 wire. Therefore, the design calls for 2 No. 6 WP and 1 No. 8 WP.

The poultry house and shop are supplied by one set of feeder wires. The poultry house is 180 feet from the residence and the shop is 80 feet from the poultry house. The total computed load of shop and poultry house is 199 amperes (table 2, page 14) and No. 1 WP wire is needed for the two live conductors as a minimum size. On the neutral, at least the larger pieces of equipment operated on 230 volts, such as the welder, may be deducted, so the neutral wire could be No. 4 WP wire. The probable maximum demand on this feeder is affected by both the shop and the poultry operations. Where two different loads are supplied by a single feeder, as in this building, 100 per cent of the probable maximum demand of the larger load and 50 per cent of the smaller load can be used to estimate the probable combined demand on the feeder. The probable maximum demand of the poultry house is 100 amperes, which is the larger load, and that of the shop is 49 amperes, therefore, 100 + ½ of 49 (or 25) = 125 amperes as the probable feeder demand. Taking this demand at 2 per cent voltage drop over 180 feet, No. 00 wire is required

(table 9, page 69). This is larger than the minimum determined by the computed load, so the larger design is used. Two No. 00 WP wires will be needed for the "hot" feeder wires.

Since the 230-volt loads are not included on the neutral load, the neutral wire could safely be No. 4, but to comply with Code it should be No. 1 WP. Therefore, the design of the system will be 2 No. 00WP and 1 No. 1 WP wires.

The service entrance wires for the residence carry the entire computed load for all the buildings. This total computed load is 448 amperes, and would require 1000 M.C.M. wire.

The information for this problem is summarized in table 4.

This problem shows clearly the larger sizes of feeder wires needed for the indoor metering system as compared with pole metering. In addition to the extra cost of the feeder wires, there may be the cost of a 600-ampere service-entrance switch, fused at 450 amperes in the residence or a wire channel with separate disconnect switches for each building. Each building in addition must have its own separate service entrance "combination" switch or wiring panel.

Main Service Entrance

The main service entrance (figures 34 to 37, and 48 and 50) must be large enough to supply all the buildings on the farm. This main service may be either in or on one of the buildings (metering on a building) or on a pole (pole metering) for central distribution.

In general, the main service entrance and meter should be near or in the building where the most electrical equipment will be used. If a considerable number of appliances will be used in each of two or more buildings, such as a residence and a dairy barn, then it may be more economical to locate the meter midway between these buildings. This location might be on a pole in the farm yard or on some building near the center of the farm yard. From this point, a separate feeder line would extend to each principal building. The advantage is that if changes must be made later in one building, the wiring to the other buildings is not disturbed. Also, it is not necessary to bring the entire electrical load into one building and then bring a part of it out again.

Whether the meter is indoors, outdoors on a building, or on a pole, depends not only upon the wiring layout of the farm but upon the rules and regulations of the organization rendering the electric service. The rules of the various electric-power suppliers differ; therefore, it is always advisable for the farmer and the electrician to consult the electric-power

supplier. In that way, a location that will be usually advantageous and satisfactory can be determined.

When the main service entrance is in one of the buildings, the size of service entrance must be adequate not only for that building but for all other buildings on the farm. For many farms this means a 3-wire, 200-ampere or larger main service entrance.

All too frequently it becomes necessary to make extensive and costly changes in the service-entrance wiring when one wants to add heavy-duty electrical, labor-saving equipment.

Provision for adequate capacity for reasonable future needs when wiring is first installed is but a fraction of the cost of making changes at a later date.

The following problem with pole metering and indoor metering further illustrates the size of service required for farm-wiring systems. The farm previously used in calculating the size of feeder wires serves as an example.

This requires 700 M.C.M. type RH, or 1000 M.C.M. type T or TW, entrance-wire conductors.

The size of the main-service switch is calculated in the same manner as that for the individual building service entrance, which has been previously illustrated:

A 600-ampere entrance switch fused at 500 amperes would be adequate for this load. It is possible, however, to use a wire channel with two 200-ampere switches, one 100-ampere switch, and one 60-ampere switch at the service in place of the 600-ampere switch. One 200-ampere switch would control the barn circuit, one 100-ampere switch would control the residence circuit, one 60-ampere switch would control the brooder-house circuit, and a 200-ampere switch would control the poultry house and shop circuits.

The alternate method of main service is pole service, in which the probable maximum demand is used to calculate the size of conductors used on the meter pole.

The maximum demand of 212 amperes requires No. 0000 type RH or No. 250 M.C.M. type T. or TW entrance conductors in the "meter loop." This is the set of wires installed on the meter pole to connect the power supplier's meter with the

Table 5. Metering on a Building

Buildings	Computed load
	Amperes
Residence	91
Dairy barn	107
Poultry house	126
Brooder house	51
Shop	73
Total	448
Load	***Amperes***
Total computed load	448
Less 25 per cent of largest motor	7
	441
Plus 200 per cent of largest motor	56
Total	497

Table 6. Probable Maximum Demand of Farm-pole Service

Building	Amperes	Percentage*	Probable load
		Percent	*Amperes*
Residence	81	50	40
Dairy	64	50	32
Poultry	100	100	100
Brooder	33	50	16
Shop	49	50	24
Total			212

* This percentage is an assumed maximum, depending upon seasonal work and use of electrical equipment.

service wires bringing the power supply in from the power line.

Generally it is considered good practice to have the capacity of the pole-meter equipment at least equal to the capacity of the largest service supplied from the meter pole. In this example the poultry house has No. 0 wire in the service entrance. This checks with the calculations above, as the "meter loop" is 0000 and is larger than the service entrance size of any individual building. Some power suppliers have standard specifications for pole-meter installations such as 100, 150, and 200 ampere, with wire sizes specified accordingly.

Rewiring and Checking the Farm Wiring System

The necessity of an adequate number of circuits, a large enough building-service entrance, main service switch, and feeder wires has been shown.

The following itemized sheets enable the individual farmer to calculate the total computed load, the probable maximum demand, the size of the building service entrance, and the size of feeder wires required for his farm. These are suggested outlines that might be used by a farmer or electrician to calculate the requirements of a dairy barn or a poultry house.

POULTRY

Items	Total computed load	Probable maximum demand *
	Amperes at 230 volts	*Amperes at 230 volts*
Lights ____ × 1.0 amperes = ____ amperes at 115 volts		
____ Amperes at 115 volts / 2 =	_____	_____
Convenience outlets ____ × 1.5 amperes = ____ amperes at 115 volts		
Amperes at 115 volts / 2 =	_____	_____
____ water heaters = ____ watts		
____ egg washers = ____ watts		
____ heating units = ____ watts		
_____ ____ watts		
_____ ____ watts		
Total watts ÷ 230 =		
_____	_____	_____
_____	_____	_____
_____	_____	_____
Total	_____	_____

Total computed load	_____	amperes
Size of service switch	_____	amperes
Size of service-entrance wires	_____	
Probable maximum demand	_____	amperes
Distance source to service	_____	feet
Size of feeder wires	_____	

* Enter amperage of maximum amount of equipment which will be operating at the same time.

DAIRY

Items	Total computed load	Probable maximum demand *
	Amperes at 230 volts	*Amperes at 230 volts*
Lights ____ × 1.5 amperes = ____ amperes at 115 volts		
____ Amperes at 115 volts / 2 =	_____	_____
Convenience outlets ____ × 1.5 amperes = ____ amperes at 115 volts		
____ Amperes at 115 volts / 2 =		
Milker ____ horsepower	_____	_____
Cooler ____ horsepower	_____	_____
Water heater ____ watts ÷ 230 volts = amperes	_____	_____
Water pump ____ horsepower	_____	_____
Milk-house heater ____ watts ÷ 230 volts = amperes	_____	_____
____ horsepower dryer	_____	_____
____ gutter cleaner	_____	_____
____ gutter-cleaner elevator	_____	_____
____ silo unloader	_____	_____
Electric fans (no.) × amperes (fan motor)	_____	_____
Other		
_____	_____	_____
_____	_____	_____
_____	_____	_____
Total	_____	_____
Total computed load	_____	amperes
Size of service switch	_____	amperes
Size of service-entrance wires	_____	
Probable maximum demand	_____	amperes
Distance source to service	_____	feet
Size of feeder wires	_____	

* Enter amperage of maximum amount of equipment which will be operating at the same time.

Kilowatt Hour Consumption for Electrical Equipment

Equipment	Approximate kilowatt hour consumption
In the House	
House lights	80 per month
House water pump	4 per month
Washing machine	3 per month
Flat iron	6 per month
Toaster	3 per month
Radio	10 per month
Kitchen refrigerator	35 per month
Water heater	300 per month or 75 per person
Electric range	25 per person per month
Electric clock	1½ per month
Fan	1 for each 10 hours use
Vacuum cleaner	3 per year
Dishwasher	45 per month
Oil furnace	200 to 500 per year
Farm food freezer	
15 cubic foot	75 to 120 per month
24 cubic foot	150 per month
30 cubic foot	200 per month
Automatic washer	3 per month
Clothes dryer	50 per month
Television	18 per month
On the Farm	
Barn lighting	30 per month
Water pumping	
Shallow-well	1 per 1000 gallons
Deep-well	1 per 500 gallons
Milking machine	½ per 10-gallon can
Milk cooler	1 per 10-gallon can
Dairy water heater	25 to 35 per 100 gallons
Dairy ventilation (20 cows)	150 per month
Poultry-house ventilation	1 per 100 hens per day
Poultry-house lights	15 per month per 100 hens
Poultry water warmers	4 per month per 100 hens
Hover chick brooder	½ to 1½ per chick (6 to 8 weeks)
Silo unloading	1 per 20 cows per day
Barn cleaner	1 per 20 cows per day
Fractional horsepower motors	1 per horsepower hour
Battery brooder	2 per chick
Grinding feed	
Sawing wood	3 per cord
Silo filling	1 per ton
Welder	5 per month
5-horsepower motor	5 per hour
Hay drying	55 per ton

Table 7. Wire Sizes Required for Loads up to 400 Amperes at 230 Volts, Based on a 1 per cent Voltage Drop

Load		Length of run in feet																
Watts	Amperes	30	40	50	60	70	80	90	100	125	150	175	200	225	250	275	300	350	400
		Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1,150	5	14	14	14	14	14	14	12	12	12	10	10	10	8	8	8	8	6	6
1,380	6	14	14	14	14	14	12	12	12	10	10	10	8	8	8	8	6	6	6
1,610	7	14	14	14	14	12	12	12	12	10	10	8	8	8	8	6	6	6	6
1,840	8	14	14	14	12	12	12	12	10	10	8	8	8	8	6	6	6	6	4
2,070	9	14	14	12	12	12	12	10	10	10	8	8	8	6	6	6	6	4	4
2,300	10	14	14	12	12	12	10	10	10	8	8	8	6	6	6	6	4	4	4
2,760	12	14	12	12	10	10	10	10	8	8	6	6	6	6	4	4	4	4	2
3,220	14	14	12	12	10	10	10	8	8	8	6	6	6	4	4	4	4	2	2
3,680	16	12	12	10	10	10	8	8	8	6	6	6	4	4	4	4	2	2	2
4,140	18	12	12	10	10	8	8	8	6	6	6	4	4	4	4	2	2	2	2
4,600	20	12	10	10	8	8	8	8	6	6	4	4	4	4	2	2	2	2	1
5,750	25	10	10	8	8	8	6	6	6	4	4	4	2	2	2	2	1	1	0
6,900	30	10	8	8	6	6	6	6	4	4	2	2	2	2	1	1	0	0	00
8,050	35	10†	8	8	6	6	6	4	4	4	2	2	2	1	1	0	0	00	00
9,200	40	8	8	6	6	6	4	4	4	2	2	2	1	1	0	0	00	00	000
10,350	45	8*	6	6	6	4	4	4	4	2	2	1	1	0	0	00	00	000	000
11,500	50	8†	6	6	4	4	4	4	2	2	1	1	0	0	00	00	000	000	0000
13,800	60	6*	6*	4	4	4	2	2	2	1	1	0	00	00	000	000	000	0000	250M§
16,100	70	6†	6†	4	4	2	2	2	2	1	0	00	00	000	000	0000	0000	250M	300M
18,400	80	6†	4*	4*	2	2	2	2	1	0	00	00	000	000	0000	0000	250M	300M	300M
20,700	90	6‡	4†	4†	2	2	2	1	1	0	00	000	000	0000	0000	250M	250M	300M	350M
23,000	100	4†	4†	2*	2*	2*	1	1	0	00	000	000	0000	0000	250M	300M	300M	350M	400M
26,450	115	4‡	2*	2*	2*	1	0	0	0	00	000	0000	0000	250M	300M	300M	350M	400M	500M
29,900	130	4‡	2†	2†	1*	1*	0	00	00	000	0000	0000	250M	300M	300M	350M	350M	500M	500M
33,350	145	4‡	2‡	1†	1†	0*	00	00	00	0000	0000	250M	300M	350M	350M	400M	400M	500M	
36,800	160	2‡	2‡	1†	0†	0†	00	00	000	0000	250M	300M	300M	350M	400M	400M	500M	500M	
41,400	180	2‡	1‡	1‡	0†	00†	00†	000*	000*	0000	250M	300M	350M	400M	500M	500M	500M		
46,000	200	2‡	1‡	0‡	00†	00†	000*	000*	0000*	250M	300M	350M	400M	500M	500M	500M			

Table 7 (concluded)

Load		Length of run in feet																	
Watts	Amperes	30	40	50	60	70	80	90	100	125	150	175	200	225	250	275	300	350	400
		Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
51,750	225	0‡	0‡	0‡	00†	000†	000†	0000*	0000*	300M	350M	400M	500M	500M					
57,500	250	00‡	00‡	00‡	000†	000†	0000†	0000†	250M*	300M*	350M	500M	500M						
63,250	275	00‡	00‡	00‡	000‡	0000†	0000†	250M†	300M*	350M*	400M	500M	500M						
69,000	300	000‡	000‡	000‡	000‡	0000†	250M†	250M†	300M†	350M*	500M	500M							
74,750	325	0000‡	0000‡	0000‡	0000‡	0000‡	250M†	300M†	300M†	400M*	500M								
80,500	350	0000‡	0000‡	0000‡	0000‡	250M‡	300M†	300M†	350M†	500M*	500M*								
86,250	375	250M‡§	250M‡	250M‡	250M‡	250M‡	300M‡	350M†	350M†	500M*									
92,000	400	250M‡	250M‡	250M‡	250M‡	300M‡	300M‡	350M†	400M†	500M†									

* Type RH or RHW cable or raceway; all types in air. For other types in cable or raceway, refer to table 1 of National Electrical Code for minimum size permissible.

† Based on weatherproof or Type TW in air. For wires in cable or raceway refer to table 1 of National Electrical Code for minimum size permissible.

‡ Based on weatherproof wire in air. For all other conditions, refer to tables 1 and 2 of National Electrical Code for minimum size permissible.

§ M = thousand circular mils.

Note: Conductors in overhead spans must be at least No. 10 for spans up to 50 feet and No. 8 for longer spans. See 1953 NE Code, Section 7314b. Feeder conductors must be at least No. 10, Sec. 1953 NE Code, Section 2201.

Table 8. Wire Sizes Required for Loads up to 200 Amperes at 115 Volts, Based on a 1 per cent Voltage Drop

Load		Length of run in feet																	
Watts	Amperes	30	40	50	60	70	80	90	100	125	150	175	200	225	250	275	300	350	400
		Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
575	5	14	14	12	12	12	10	10	10	8	8	6	6	6	6	4	4	4	4
600	6	14	12	12	12	10	10	10	8	8	6	6	6	6	4	4	4	4	2
805	7	14	12	12	10	10	10	8	8	8	6	6	6	4	4	4	4	2	2
920	8	12	12	10	10	10	8	8	8	6	6	6	4	4	4	2	2	2	2
1,035	9	12	12	10	10	8	8	8	8	6	6	4	4	4	4	2	2	2	2
1,150	10	12	10	10	8	8	8	8	6	6	4	4	4	4	2	2	2	2	1
1,380	12	12	10	8	8	8	6	6	6	4	4	4	2	2	2	2	2	1	0
1,610	14	10	10	8	8	6	6	6	6	4	4	2	2	2	2	1	1	0	0
1,840	16	10	8	8	6	6	6	6	4	4	2	2	2	2	1	1	0	0	00
2,070	18	10	8	8	6	6	6	4	4	4	2	2	2	1	1	0	0	00	00
2,300	20	8	8	6	6	6	4	4	4	2	2	2	1	1	0	0	00	00	000
2,875	25	8	6	6	4	4	4	4	2	2	1	1	0	0	00	00	000	000	0000
3,450	30	8	6	4	4	4	2	2	2	1	1	0	00	00	000	000	000	0000	250M§
4,025	35	6	6	4	4	2	2	2	2	1	0	00	00	000	000	0000	0000	250M	300M
4,600	40	6	4	4	2	2	2	2	1	0	00	00	000	000	0000	0000	250M	300M	300M
5,175	45	6	4	4	2	2	2	1	1	0	00	000	000	0000	0000	250M	250M	300M	350M
5,750	50	4	4	2	2	2	1	1	0	00	000	000	0000	0000	250M	300M	300M	350M	400M
6,900	60	4	2	2	2	1	0	0	00	000	000	0000	250M	250M	300M	350M	350M	400M	500M
8,050	70	4	2	2	1	0	0	00	00	000	0000	250M	300M	300M	350M	400M	400M	500M	
9,200	80	2	2	1	0	0	00	00	000	0000	250M	300M	300M	350M	400M	500M	500M	500M	
10,350	90	2	1	1	0	00	00	000	000	0000	250M	300M	350M	400M	500M	500M	500M		
11,500	100	2*	1	0	00	00	000	000	0000	250M	300M	350M	400M	500M	500M				
13,225	115	2*	1*	0	00	000	0000	0000	0000	300M	350M	400M	500M	500M					
14,950	130	1*	0*	00	000	000	0000	0000	250M	300M	400M	500M	500M						
16,675	145	1†	0*	00	000	0000	0000	250M	300M	350M	500M	500M							
18,400	160	0†	00*	000	000	0000	250M	300M	300M	400M	500M								
20,700	180	0†	00†	000*	0000	250M	300M	300M	350M	500M	500M								
23,000	200	00†	000*	0000*	250M§	300M	300M	350M	400M	500M									

* Type RH or RHW cable or raceway; all types in air. For other types in cable or raceway, refer to table 1 of National Electrical Code for minimum size permissible.

† Based on weatherproof or Type TW in air. For wires in cable of raceway, refer to table 1 of National Electrical Code for minimum size permissible.

‡ Based on weatherproof wire in air. For all other conditions, refer to tables 1 and 2 of National Electrical Code for minimum size permissible.

§ M = thousand circular mils.

Note: Conductors in overhead spans must be at least No. 10 for spans up to 50 feet and No. 8 for longer spans. See 1953 NE Code, Section 7314b. Feeder conductors must be at least No. 10, Sec. 1953 NE Code, Section 2201.

Table 9. Wire Sizes Required for Loads up to 400 Amperes at 230 Volts, Based on a 2 per cent Voltage Drop

Load		Length of run in feet																
Watts	Amperes	40	50	60	70	80	90	100	125	150	175	200	225	250	275	300	350	400
		Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1,150	5	14	14	14	14	14	14	14	14	14	12	12	12	12	10	10	10	10
1,380	6	14	14	14	14	14	14	14	14	12	12	12	12	10	10	10	10	8
1,610	7	14	14	14	14	14	14	14	14	12	12	12	10	10	10	10	8	8
1,840	8	14	14	14	14	14	14	14	12	12	12	10	10	10	10	8	8	8
2,070	9	14	14	14	14	14	14	12	12	12	10	10	10	10	8	8	8	8
2,300	10	14	14	14	14	14	12	12	12	10	10	10	10	8	8	8	8	6
2,760	12	14	14	14	14	12	12	12	10	10	10	8	8	8	8	6	6	6
3,220	14	14	14	14	12	12	12	12	10	10	8	8	8	8	6	6	6	6
3,680	16	12	12	12	12	12	12	10	10	8	8	8	6	6	6	6	6	4
4,140	18	12	12	12	12	12	10	10	10	8	8	6	6	6	6	6	4	4
4,600	20	12	12	12	12	10	10	10	8	8	8	6	6	6	6	4	4	4
5,750	25	10	10	10	10	10	10	8	8	6	6	6	6	4	4	4	4	2
6,900	30	10	10	10	10	8	8	8	6	6	6	4	4	4	4	4	2	2
8,050	35	10†	10†	10†	8	8	8	8	6	6	4	4	4	4	2	2	2	2
9,200	40	10†	10†	8	8	8	8	6	6	4	4	4	4	2	2	2	2	1
10,350	45	10‡	10‡	8*	8*	8*	6	6	6	4	4	4	2	2	2	2	1	1
11,500	50	10‡	8†	8†	8†	6	6	6	4	4	4	2	2	2	2	1	1	0
13,800	60	8‡	8‡	6*	6*	6*	6*	4	4	2	2	2	2	1	1	1	0	00
16,100	70	8‡	8‡	6†	6†	6†	4	4	4	2	2	2	1	1	0	0	00	00
18,400	80	6†	6†	6†	6†	4*	4*	4*	2	2	2	1	1	0	0	00	00	000
20,700	90	6‡	6‡	6‡	4†	4†	4†	4†	2	2	1	1	0	0	00	00	000	000
23,000	100	6‡	6‡	4†	4†	4†	4†	2*	2*	1	1	0	0	00	00	000	000	0000
26,450	115	4‡	4‡	4‡	4‡	2*	2*	2*	2*	1*	0	00	00	00	000	000	0000	250M§
29,900	130	4‡	4‡	4‡	2†	2†	2†	2†	1*	0*	0*	00	000	000	000	0000	0000	250M
33,350	145	2‡	2‡	2‡	2‡	2‡	2‡	1†	0*	0*	00	00	000	0000	0000	0000	250M	300M
36,800	160	2‡	2‡	2‡	2‡	2‡	1†	1†	0†	00*	00*	000	000	0000	0000	250M	300M	300M
41,400	180	1‡	1‡	1‡	1‡	1‡	1‡	1‡	0†	00†	000*	000*	0000	0000	250M	300M	300M	350M
46,000	200	1‡	1‡	1‡	1‡	1‡	1‡	0‡	00†	000*	000*	0000*	0000*	250M	300M	300M	350M	400M

Table 9 (concluded)

Load		Length of run in feet																
Watts	Amperes	40	50	60	70	80	90	100	125	150	175	200	225	250	275	300	350	400
		Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
51,750	225	0‡	0‡	0‡	0‡	0‡	0‡	0‡	00†	000†	0000*	0000*	250M*	300M	300M	350M	400M	500M
57,500	250	00‡	00‡	00‡	00‡	00‡	00‡	00‡	000†	0000†	0000†	250M*	300M*	300M*	350M	350M	400M	500M
63,250	275	00‡	00‡	00‡	00‡	00‡	00‡	00‡	000‡	0000†	250M†	300M*	300M*	350M*	350M*	400M	500M	
69,000	300	000‡	000‡	000‡	000‡	000‡	000‡	000‡	0000†	250M†	250M†	300M†	350M*	350M*	400M*	500M	500M	
74,750	325	0000‡	0000‡	0000‡	0000‡	0000‡	0000‡	0000‡	0000‡	250M†	300M†	300M†	350M†	400M*	500M*	500M*		
80,500	350	0000‡	0000‡	0000‡	0000‡	0000‡	0000‡	0000‡	0000‡	250M‡	300M†	350M†	400M†	400M†	500M*	500M*		
86,250	375	250M‡	250M‡	250M‡	250M‡	250M‡	250M‡	250M‡	250M‡	300M†	350M†	350M†	400M†	500M†	500M†			
92,000	400	250M‡	250M‡	250M‡	250M‡	250M‡	250M‡	250M‡	250M‡	300M‡	350M†	400M†	500M†	500M†				

* Type RH or RHW cable or raceway; all types in air. For other types in cable or raceway, refer to table 1 of National Electrical Code for minimum size permissible.

† Based on weatherproof or Type TW in air. For wires in cable of raceway, refer to table 1 of National Electrical Code for minimum size permissible.

‡ Based on weatherproof wire in air. For all other conditions, refer to tables 1 and 2 of National Electrical Code for minimum size permissible.

§ M = thousand circular mils.

Note: Conductors in overhead spans must be at least No. 10 for spans up to 50 feet and No. 8 for longer spans. See 1953 NE Code, Section 7314b. Feeder conductors must be at least No. 10, Sec. 1953 NE Code, Section 2201.

Table 10. Wire Sizes Required for Loads up to 200 Amperes at 115 Volts, Based on a 2 per cent Voltage Drop

Load		Length of run in feet																	
Watts	Amperes	30	40	50	60	70	80	90	100	125	150	175	200	225	250	275	300	350	400
		Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
575	5	14	14	14	14	14	14	12	12	12	10	10	10	8	8	8	8	6	6
600	6	14	14	14	14	14	12	12	12	10	10	10	8	8	8	8	6	6	6
805	7	14	14	14	14	12	12	12	12	10	10	8	8	8	8	6	6	6	6
920	8	14	14	14	12	12	12	12	10	10	8	8	8	8	6	6	6	6	4
1,035	9	14	14	12	12	12	12	10	10	10	8	8	8	6	6	6	4	4	4
1,150	10	14	14	12	12	12	10	10	10	8	8	8	6	6	6	6	4	4	4
1,380	12	14	12	12	10	10	10	10	8	8	6	6	6	6	4	4	4	4	2
1,610	14	14	12	12	10	10	10	8	8	8	6	6	6	4	4	4	4	2	2
1,840	16	12	12	10	10	10	8	8	8	6	6	6	4	4	4	4	2	2	2
2,070	18	12	12	10	10	8	8	8	6	6	6	4	4	4	4	2	2	2	2
2,300	20	12	10	10	8	8	8	8	6	6	4	4	4	4	2	2	2	2	1
2,875	25	10	10	8	8	8	6	6	6	4	4	4	2	2	2	2	1	1	0
3,450	30	10	8	8	6	6	6	6	4	4	2	2	2	2	1	1	0	0	00
4,025	35	10†	8	8	6	6	6	4	4	4	2	2	2	1	1	0	0	00	00
4,600	40	8	8	6	6	6	4	4	4	2	2	2	1	1	0	0	00	00	000
5,175	45	8*	8*	6	6	4	4	4	4	2	2	1	1	0	0	00	00	000	000
5,750	50	8†	6	6	4	4	4	4	2	2	1	1	0	0	00	00	000	000	0000
6,900	60	6*	6*	4	4	4	2	2	2	1	1	0	00	00	000	000	000	0000	250M§
8,050	70	6†	6†	4	4	2	2	2	2	1	0	00	00	000	000	0000	0000	250M	300M
9,200	80	6†	4*	4*	2	2	2	2	1	0	00	000	000	000	0000	0000	250M	300M	300M
10,350	90	6‡	4†	4†	2	2	2	1	1	0	00	000	000	0000	0000	250M	250M	300M	350M
11,500	100	4†	4†	2*	2*	2*	1	1	0	00	000	000	0000	0000	250M	300M	300M	350M	400M
13,225	115	4‡	2*	2*	2*	1	0	0	0	00	000	0000	0000	250M	300M	300M	350M	400M	500M
14,950	130	4‡	2†	2†	1*	1*	0	00	00	000	0000	0000	250M	300M	300M	350M	350M	500M	500M
16,675	145	4‡	2‡	1†	1†	0*	00	00	00	0000	0000	250M	300M	350M	350M	400M	400M	500M	
18,400	160	4‡	2‡	1†	0†	0†	00	00	000	0000	250M§	300M	300M	350M	400M	400M	500M	500M	
20,700	180	2‡	2‡	1‡	0†	00†	00†	000*	000*	0000	250M	300M	350M	400M	500M	500M	500M		
23,000	200	2‡	1‡	0‡	00†	00†	000*	000*	0000*	250M	300M	350M	400M	500M	500M	500M			

* Type RH or RHW cable or raceway; all types in air. For other types in cable or raceway, refer to table 1 of National Electrical Code for minimum size permissible.

† Based on weatherproof or Type TW in air. For wires in cable of raceway, refer to table 1 of National Electrical Code for minimum size permissible.

‡ Based on weatherproof wire in air. For all other conditions, refer to tables 1 and 2 of National Electrical Code for minimum size permissible.

§ M = thousand circular mils.

Note: Conductors in overhead spans must be at least No. 10 for spans up to 50 feet and No. 8 for longer spans. See 1953 NE Code, Section 7314b. Feeder conductors must be at least No. 10, Sec. 1953 NE Code, Section 2201.

Table 11. Wire Sizes for Individual Single-Phase Motors, Based on 2 per cent Voltage Drop on Full Load Current

Motor	Voltage	Approximate full load current	Length of run in feet												
			100	150	200	250	300	350	400	500	600	700	800	900	1000
Horsepower	*Volts*	*Amperes*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
1/20	115	2.4	14	14	12	12	10	10	10	8	8	8	6	6	6
1/12	115	2.6	14	14	12	12	10	10	10	8	8	6	6	6	6
1/8	115	2.8	14	14	12	12	10	10	8	8	8	6	6	6	6
1/6	115	3.2	14	12	12	10	10	8	8	8	6	6	6	4	4
1/4	115	4.6	12	12	10	8	8	8	6	6	6	4	4	4	2
1/3	115	5.1	12	10	10	8	8	6	6	6	4	4	4	2	2
1/2	115	7.4	10	8	8	6	6	6	4	4	2	2	2	2	1
3/4	115	10.2	10	8	6	6	4	4	4	2	2	2	1	0	0
1/6	230	1.6	14	14	14	14	14	14	14	14	12	12	12	10	10
1/4	230	2.3	14	14	14	14	14	14	12	12	12	10	10	10	8
1/3	230	2.6	14	14	14	14	14	12	12	12	10	10	10	8	8
1/2	230	3.7	14	14	14	12	12	12	10	10	10	8	8	8	6
3/4	230	5.1	14	14	12	12	10	10	10	8	8	6	6	6	6
1	230	6.5	14	12	12	10	10	8	8	8	6	6	6	4	4
1-1/2	230	9.2	12	12	10	8	8	8	6	6	6	4	4	4	2
2	230	12.0	12	10	8	8	6	6	6	4	4	4	2	2	2
3	230	17.0	10	8	8	6	6	4	4	4	2	2	2	1	1
5	230	28.0	8	6	6	4	4	2	2	2	1	0	0	00	00
7-1/2	230	40.0	6	4	4	2	2	2	1	0	00	00	000	000	0000
10	230	50.0	4	4	2	2	1	1	0	00	000	000	0000	0000	250M *

* M = thousand circular mils.

Type RH or RHW in cable or raceway; all types in air. For other types in cable or raceway, refer to table 1 of National Electrical Code for minimum size permissible.

Cooperative Extension Service, New York State College of Agriculture at Cornell University and the U.S. Department of Agriculture cooperating. In furtherance of Acts of Congress May 8, June 30, 1914. M. C. Bond, Director of Extension, Ithaca, New York.